Lower Passaic River Restoration Project

Draft Geochemical Evaluation (Step 2)

February 2006

Version 2006/02/08

PREPARED BY:
Malcolm Pirnie, Inc.
104 Corporate Park Drive
White Plains, NY 10602

FOR:
US Environmental Protection Agency
Region II

US Army Corps of Engineers
Kansas City District
*Contract No.
DACW41-02-D-0003*

DRAFT GEOCHEMICAL EVALUATION (STEP 2)

LOWER PASSAIC RIVER RESTORATION PROJECT

Prepared by:

Malcolm Pirnie, Inc., in conjunction with Battelle, Inc. and HydroQual, Inc.

February 2006

Version: 2006/02/08

Contents
Draft Geochemical Evaluation (Step 2)
for the Lower Passaic River Restoration Project

List of Tables
Draft Geochemical Evaluation (Step 2)
for the Lower Passaic River Restoration Project

List of Figures
Draft Geochemical Evaluation (Part 2)
for the Lower Passaic River Restoration Project

1.0   INTRODUCTION AND SUMMARY

The geochemical evaluation presented in this document represents an important step in the on-going remedial investigation and feasibility study for the Lower Passaic River. Malcolm Pirnie, Inc. prepared this introductory fate-and-transport analysis of historical data from the Lower Passaic River, which includes work prepared by HydroQual, Inc. and Battelle, Inc., to examine the following:

- The net transport of solids from the Lower Passaic River to Newark Bay.
- The vertical and horizontal extent of contamination in the sediments of the Lower Passaic River.
- The historical contamination in the water column of the Lower Passaic River.
- The historical contamination in the biota of the Lower Passaic River.
- The locations, relative magnitudes, and chemical constituents of historical and current (*circa* 1995) sources of contamination to the Lower Passaic River, including the region above the Dundee Dam.
- The general nature of the historical and current sources (*e.g.*, local, industrial, regional, and watershed-wide)
- The effects of transport processes on contaminants in the Lower Passaic River.
- The volume of contaminated sediments in the Lower Passaic River.
- The possible identification of localized areas of elevated contamination in River Mile (RM) 0 to 7.

1.1   OVERVIEW OF EVALUATION AND SUMMARY

To explore these topics, several different approaches were applied to examine the available data from both a geochemical and a geophysical perspective. In general, the geochemical data (*i.e.*, measurements of contamination in sediments, water, and biota) were limited to sampling efforts conducted between 1985 and 2000. Except for the upcoming results from the US Environmental Protection Agency (USEPA) 2005 field efforts conducted by Malcolm Pirnie, Inc. and its subcontractors, relatively little geochemical data are available after 2000. The geophysical data (*i.e.*, bathymetric surveys) encompass a similar, but more recent time period, from 1989 to 2004. In addition to these datasets, this analysis also makes extensive use of the 2005 side scan sonar survey of the Lower Passaic River conducted for the New Jersey Department of Transportation, Office of Maritime Resources (NJDOT-OMR; Aqua Surveys, Inc., 2005). This survey provides an important framework for interpreting historical data since the interpretation of the survey data resulted in a detailed map of sediment texture throughout the Lower Passaic River. Likewise, the sediment volume analysis incorporates the recent geotechnical boring data obtained by Malcolm Pirnie, Inc. in June 2005 because of the uniqueness of the dataset for the purpose of estimating the thickness of recent, fine-grained sediments.

Based on the analyses presented in this document, a series of important conclusions and observations can be drawn concerning the Lower Passaic River contamination, fate and

transport of contaminants, and the suitability of the existing data for an interim remedial measure. Conclusions and observations are listed below without assigning a relative level of importance:[1]

- The Lower Passaic River is net depositional for the period examined; however 20 to 50 percent of the solids, which enter from the Upper Passaic River and tributaries, are transported out to Newark Bay.
- Sediment deposition rates in the Lower Passaic River (RM 0.9 to 7) have a high degree of spatial variability, varying from about -6 inch/year of erosion to about +8 inch/year of deposition over short distances.
- Consistent with the observations by Bopp *et al.* (1991a) and Chaky (2003) for Newark Bay, dated sediment cores for the Lower Passaic River show the major releases of 2,3,7,8-TCDD beginning in the 1950s and peaking in the 1960s.
- The diagnostic ratio of 2,3,7,8-TCDD/Total TCDD of 0.7 to 0.8 can be used to trace the Lower Passaic River 2,3,7,8-TCDD source throughout the Newark Bay complex and over the last 60 years.
- Dated sediment cores confirm the possible use of Total DDT as a measure of the vertical extent of 2,3,7,8-TCDD contamination, but there may be issues with measurement sensitivity for Total DDT if this approach is used.
- Elevated concentrations of arsenic, chromium, copper, lead, Total PAH, and benzo[a]pyrene occur at depth in dated sediment cores, usually reaching a maximum at the core bottom, indicating that the vertical extent of these contaminants is undefined. Mercury and cadmium also remain above background, at depth.
- Total PCB is found throughout the Lower Passaic River but is among the "shallowest" of contaminants. Aroclor 1248 is the most commonly reported PCB mixture, typically comprising 60 percent or more of the Total PCB burden.
- Surface sediment data at RM 3 to 4.5 suggest that this region may have a number of locations undergoing erosion and exposing older, more contaminated sediments. This conclusion requires further evaluation.
- Evidence suggests the major historical loads (*circa* 1963) of cadmium, lead, mercury, and Total PCB primarily originated in the Upper Passaic River above the Dundee Dam. A substantial load of copper also originated above the Dundee Dam, but an additional source was present downriver. Smaller sources of contamination, particularly mercury, may also have existed in the Lower Passaic River (RM 0 to 7.0).
- Under more recent conditions (*circa* 1985-1995), the Upper Passaic River remains a major source of cadmium, mercury, and lead and an important source of Total PCB. In addition, evidence suggests that in 1995 at least two sources exist in the Lower Passaic River (one at or below RM 1 and one at or above RM 7) for arsenic and chromium. Evidence also exists for at least one Lower Passaic River source for cadmium, mercury, and Total PCB as well.
- Little (less than 1 percent) of the historical 2,3,7,8-TCDD contamination in the Lower Passaic River originated above the Dundee Dam. Current loads of 2,3,7,8-TCDD

---

[1] Reader is referred to Section 7.0 for acronyms and Section 2.0 for definition of terms.

from above the dam represent only about 2 percent of the total load from the Lower Passaic River.

- A small fraction of the Total DDT load to the Lower Passaic River originated upriver of the Dundee Dam, at least, since 1963. The importance of upriver loads prior to 1963 could not be assessed.

- Total PAH contamination appears to be derived primarily from combustion-related processes, probably manufactured gas plants.

- Concurrent mass balance analysis of loads to Newark Bay for 2,3,7,8-TCDD and Total TCDD resulted in a revised solids mass balance [relative to Lowe *et al.*, (2005)] for Newark Bay with Lower Passaic River solids comprising approximately 10 percent of the total amount of solids accumulating in the bay.

- Mass balance results for 2,3,7,8-TCDD indicate that, currently, more than 80 percent of the 2,3,7,8-TCDD accumulating in Newark Bay must originate from the Lower Passaic River. No other single source delivered more than 10 percent of the load.

- Mass balance results for mercury show that, despite the higher mercury concentrations in the Lower Passaic River relative to Newark Bay, the Lower Passaic River is responsible for approximately only 20 percent of the total annual mercury load to the bay. Moreover, the known quantifiable sources of mercury to Newark Bay cannot account for the annual accumulation of mercury in the sediment beds of the bay. The "missing" mercury represents the largest single "source" of mercury to the bay, constituting roughly 35 percent of the annual mercury load. The next largest "source" is the solids delivered by the Kill van Kull, which represent about 30 percent of the annual load to Newark Bay. Note that these percentages are subject to revision when more data for Newark Bay, the Arthur Kill, and the Kill van Kull become available. Nonetheless, a large source of mercury to Newark Bay remains unknown.

- The estimated current (*circa* 1995) total annual loads of mercury and 2,3,7,8-TCDD to Newark Bay are approximately 400 kilogram/year and 14 gram/year, respectively.

- Water column measurements of suspended matter revealed the same diagnostic ratio of 2,3,7,8-TCDD/Total TCDD observed in the sediments.

- Measurements of 2,3,7,8-TCDD in blue crab also revealed the diagnostic ratio of 2,3,7,8-TCDD/Total TCDD observed in the sediments.

- Most sediment cores did not establish the actual depth of contamination for several major contaminants, including 2,3,7,8-TCDD, Total DDT, and mercury. For each of these contaminants, no more than one third of the cores penetrated to a depth where contaminant concentrations could be considered at, or close, to background levels. However, a majority of cores (60 percent) for the Total PCB dataset did penetrate to background levels.

- Approximately 25 to 48 percent of the available cores for 2,3,7,8-TCDD, Total DDT, mercury, and Total PCB were considered very uncertain with respect to the depth of contamination since their profiles were characterized as having concentrations elevated or increasing at depth.

- Two inventory estimates were generated for the mass of each of four contaminants in the Lower Passaic River. The first estimate was based on an interpolation of core measurements; the second was based on the extrapolation of the core measurements when the core did not establish the depth of contamination. The interpolated volume is considered a minimum estimate due to the uncertainties in depth of contamination.

The extrapolated inventory represented an increase of 33 to 72 percent over the interpolated estimate.

- Contaminant inventories are generally coincident for the examined contaminants at each location, but inventories vary along the length of the Lower Passaic River with maximum values occurring near RM 1 to 2, RM 3 to 4, and RM 6 to 7.

- A high degree of spatial heterogeneity suggests that localized areas of relatively higher concentrations typically described as "hot spots" do not exist in the Lower Passaic River. Instead, "hot" regions of the river typically exist on the scale of a mile or more, nearly bank to bank in lateral extent.

- Estimates of the volume of contaminated sediment in the Lower Passaic River (RM 0.9 to 7) ranged from 2.8 to 8.0 million cubic yards with an average depth of contamination ranging from 4.6 to 13 feet. Additional investigation is required to further narrow the range of the estimate.

1.2   ORGANIZATION OF THE DOCUMENT

This document is organized into six major sections, including this introduction and summary. Section 2 "Methodology" describes the techniques and approaches used to extract and prepare the data for analysis. Section 3 "Sediment Transport" describes the interpretation of the geophysical data and estimates of a net deposition rate for the river as well as the net export of solids. Section 4 "Contaminants in the Lower Passaic River" is concerned with the geochemical analysis of the data, estimating contaminant histories, source identification and characterization, and mass balance estimates for Newark Bay. Section 5 "Volume of Contaminated Sediment" focuses on the volume of contaminated sediments and the estimation of contaminant inventories. Finally, Section 6 "Conclusions and Observations" provides a set of conclusions and observations for the document. Acronyms (Section 7.0) and References (Section 8.0) are provided at the end of the document.

This document is arranged similar to a technical article with Section 2.0 discussing methodology and Sections 3.0, 4.0, and 5.0 discussing results and interpretation. Table 1-1 outlines the corresponding methodology section and discussion section based on topic to help the reader navigate the documents.

Table 1-1: Outline of Corresponding Sections in Document

Topic	Methodology Section	Discussion Section
Annual Accumulation	2.1	3.1
Sedimentation Rate	2.1	3.2
Mass Balance of Solids	2.1	3.3
Contaminant Chronology	2.2.2	4.3
Surface Concentration	2.2.3	4.4
Source Analysis	2.2.3 and 2.3	4.5
Chemical Mass Balance	2.2 and 2.3	4.6
Geostatistical Volume Calculation	2.4	5.1
Mass Per Unit Area Calculation	2.5	5.2

2.0   METHODOLOGY

The following section describes the methodology used to complete the geochemical evaluation. Methodological information includes data sources, queries designed to extract particular data, assumptions on data, manipulation of data, and a description of formulas and calculations. Data results, discussions, and evaluations are presented elsewhere in the document (Section 3 "Sediment Transport," Section 4 "Geochronology of Contaminants," and Section 5 "Volume of Contaminated Sediment.")

2.1   SEDIMENTATION RATES AND ANNUAL ACCUMULATION

One of the goals of this geochemical investigation was to identify areas of potentially high contaminant inventory. Given that the historical contaminants in the Lower Passaic River are generally considered hydrophobic (*i.e.,* a high affinity for sediment particles), areas of thick, fine-grained sediment deposits will typically have the highest contaminant inventories. In estuarine settings, such as the Lower Passaic River, areas of rapid deposition will generally accumulate fine-grained sediments, making these rapidly depositing areas likely places for high contaminant inventories. To identify these areas, deposition rates were estimated for the river bottom by comparing bathymetric elevations obtained over time.

Several historical bathymetric surveys were compared to estimate sedimentation rates and annual solids accumulation in the Lower Passaic River. A total of eight bathymetric surveys were examined in three separate evaluations, covering a period of 15 years from 1989 to 2004. Table 2-1 provides information on the bathymetric surveys compared, including year of collection, the surveying company, and extent of the survey.

Table 2-1: Historical Bathymetric Surveys

Survey Year	Surveying Company	Extent of Coverage (River Miles)
1989	Topo-Metrics, Inc. for USACE [a]	0 to 15
1995	Tierra Solutions, Inc.	0.5 to 8.2
1996	Tierra Solutions, Inc.	0.5 to 7.0
1997	Tierra Solutions, Inc.	0.5 to 7.0
1999	Tierra Solutions, Inc.	0.9 to 7.0
2001	Tierra Solutions, Inc.	0.9 to 7.0
2002	TVGA Consultants for USACE	0 to 8.0
2004	Rogers Surveying for USACE	0 to Dundee Dam

a: USACE = US Army Corps of Engineers

Bathymetric data were manipulated following the procedure outlined in the *Preliminary Geochemical Evaluation* (Section 2.2.6; Malcolm Pirnie, Inc., 2005) and using Environmental Systems Research Institute, Inc. (ESRI) ArcGIS® 9.1[2] equipped with the 3D Analyst extension. In brief, the sounding data were converted to the National

---

[2] Mention of trade names or commercial products in this report is for purposes of conducting a remedial investigation, and does not constitute endorsement of any product or manufacturer by the U.S. Environmental Protection Agency.

Geodetic Vertical Datum of 1929 (NGVD29) to standardize data between different surveys. A bathymetric surface was then created for each dataset using a triangulated irregular network (TIN). The resulting TIN surface was then converted into a 5-foot cell-spacing grid; each grid point was assigned either an extrapolated or interpolated elevation value (units of feet). In each comparison, two bathymetric grids were compared by subtracting the elevation at each grid point, respectively. The difference between the grids is the estimated change in depth (units of feet) during the respective time period (units of years) between bathymetric surveys.

Sedimentation rates and annual accumulations were derived from the estimated change in depth between bathymetric surveys. Sedimentation rates were calculated by dividing the change in depth by the number of years[3] between surveys (units of inch/year). Rates were presented and evaluated in two formats: first as a map with colors representing different depositional rates and second as a graph of average sedimentation rates plotted per quarter river mile. In both evaluations, positive sedimentation rates indicate depositional areas while negative rates indicate non-depositional or erosional areas. Total accumulations (or losses) were calculated as the sum of the difference in elevations (feet) between the grids for a defined area. The cut and fill function in ArcGIS calculates the net solid gain or loss in cubic yards for the time period between two bathymetric surveys. (Net solids accumulation was calculated for the same area for every time period examined.) Annual solids accumulation (cubic yard/year) was then calculated by finding the difference in accumulation between comparisons. For example, the annual accumulation for 1995-1996 was determined by subtracting the 1989-1996 comparison from the 1989-1995 comparison. Likewise, the 1997-1998 accumulation was determined by subtracting the 1989-1997 comparison from the 1989-1999 comparison and then dividing by 2 years.

Note that annual accumulation may be determined by other methods; however, due to the uncertainty in these methods, their application was minimized unless necessary. For example, annual accumulation may be determined by dividing the total accumulation by the time period between the two surveys (*e.g.*, the 1989-1995 accumulation divided by 6 years). This method will, however, average-out any major events that occurred. Another example is comparing yearly surveys like the 1995 and 1996 survey to estimate annual accumulation. This method will, however, introduce additional uncertainty on the vertical control between the two surveys.

Table 2-2 lists the surveys compared in the data evaluations. Step-function plots were then generated to illustrate the change in solid accumulation over time as a function of river mile.

---

[3] While surveys are dated by month and year, the "number of years" between each survey was calculated from the dated year only; hence, only whole number years were used in the calculations.

Table 2-2: Bathymetric Surveys Compared

1989-2004 (RM 0.9 to 7)	1995-2004 (RM 0.9 to 7)	1989-2004 (RM 0 to 15)
Bathymetric Years Compared	Bathymetric Years Compared	Bathymetric Years Compared
1989-1995	1995-1996	1989-2004
1989-1996	1995-1997	
1989-1997	1995-1999	
1989-1999	1995-2001	
1989-2001	1995-2004	
1989-2002		
1989-2004		
1995-1996		
1996-1997		
2001-2002		

As noted in the *Preliminary Geochemical Evaluation* (Section 2.2.6; Malcolm Pirnie, Inc., 2005), different surveying companies followed different bathymetric surveying tracks. For example, transects followed in 1989 by Topo-Metrics, Inc. are approximately 50 feet from transects followed in 2004 by Rogers Surveying. This lack of alignment results in few direct measurement-to-measurement comparisons since at least one of the two elevation values at each grid point comparison is typically interpolated. As a result, a greater uncertainty exists for the calculated sedimentation rates and net accumulation values in survey comparisons where tracks were misaligned than survey comparisons where tracks were more closely aligned.

In addition to lack of transect alignment, bathymetric surveys collected by different surveying companies did not cover the same areas of the Lower Passaic River. However, estimates of annual accumulation can only be obtained for areas common to the surveys being compared. Hence, for each bathymetric evaluation, the survey with the smallest extent governed the area used in the annual accumulation calculation.

- For the 1989-2004 comparison (refer to Table 2-2), the Tierra Solutions, Inc. (TSI) surveys (1995 through 2001) limited the evaluation to the region between RM 0.9 and 7.0. Similarly, the 1989 Topo-Metrics, Inc. survey limited the cross-river extent since this survey did not obtain bank-to-bank coverage. The areal extent of the first evaluation was 276 acres, or 74 percent of the total area between the respective river miles [based on the shoreline as delineated in the New Jersey Department of Environmental Protection (NJDEP) Shoreline Type Geographic Information System (GIS)].
- For the 1995-2004 evaluation (refer to Table 2-2), the TSI surveys limited both the river mile extent (RM 0.9 to 7.0) and the bank-to-bank coverage. The areal extent of second evaluation was 340 acres, or 94 percent of the total area (based on the shoreline as delineated in the NJDEP Shoreline Type GIS).
- For the third evaluation (refer to Table 2-2), the 1989 Topo-Metrics, Inc. survey limited the river mile extent (RM 0 to 15) as well as the bank-to-bank coverage. The areal extent of third evaluation was 570 acres, or 68 percent of the total area (based on the shoreline as delineated in the NJDEP Shoreline Type GIS to RM 12.25;

shoreline approximated from RM 12.25 to 17). Note that a large area on the east side at the mouth of the river was not surveyed.

2.2   CONTAMINANTS IN THE SEDIMENTS

Data describing historical contaminant concentrations were extracted from the project database, which is available to the public via the web site www.ourPassaic.org. This section describes the organization of these data for the purpose of examining sediment core chronologies and surficial sediment concentrations.

Contaminants examined in this geochemical evaluation were limited to those contaminants listed as **both** a chemical of potential concern (COPC) for human health risk (Table 2 in the *Pathways Analysis Report*; Battelle, 2005a) and a chemical of potential ecological concern (COPEC) for ecological risk (Table 6 in the *Pathways Analysis Report*; Battelle, 2005a). Metals that are classified as "crustal abundance elements," including aluminum, calcium, iron, magnesium, and manganese, were excluded from the geochemical evaluation although they are listed in the *Pathways Analysis Report*. Other chemicals reported in the sediments were excluded from the evaluation because historical data were limited or the chemical was classified as a common laboratory contaminant. Table 2-3 lists the contaminants that were selected for the present geochemical evaluation.

Table 2-3: Contaminants Selected for the Geochemical Evaluation

Chemical Class	Contaminant
Metals	Antimony
	Arsenic
	Barium
	Beryllium
	Cadmium
	Chromium
	Copper
	Lead
	Mercury
	Nickel
	Silver
	Thallium
Petroleum Hydrocarbons	Total Petroleum Hydrocarbons (extractable)
Semi-Volatile Organic Compounds	1,4-Dichlorobenzene
	Butyl benzyl phthalate
	Dibenzofuran
Polycyclic Aromatic Hydrocarbons	Acenaphthene
	Acenaphthylene
	Anthracene
	Benz[a]anthracene [a]
	Benzo[a]pyrene [a]
	Benzo[b]fluoranthene [a]
	Benzo[g,h,i]perylene [a]
	Benzo[k]fluoranthene [a]
	Chrysene [a]
	Dibenz[a,h]anthracene [a]
	Fluoranthene [a]

Table 2-3 (continued)	
Polycyclic Aromatic Hydrocarbons (continued)	Fluorene
	Indeno[1,2,3-c,d]pyrene [a]
	Naphthalene
	Phenanthrene
	Pyrene [a]
Pesticides	Aldrin
	Dieldrin
	Total Chlordane
	Total Endrin
	1,1,1-Trichloro-2,2-bis(4-chlorophenyl)ethane (and its metabolites)
Polychlorinated Biphenyls	Polychlorinated Biphenyl Aroclors
	Aroclor 1248 [b]
Polychlorinated Dibenzodioxins	2,3,7,8-tetrachlorinated dibenzo-p-dioxin
	Total tetrachlorinated dibenzo-p-dioxins [b]

a: High-molecular weight polycyclic aromatic hydrocarbons
b: Compounds were considered in the analysis but no core profiles were prepared.

2.2.1 OVERVIEW OF NONDETECTED VALUES

The geochemical evaluation incorporated both detected and nondetected values into the analyses. However, nondetected values were handled differently from detected values to minimize the uncertainty in the concentrations. A brief overview of the scenarios involving nondetected concentrations is discussed below.

- If data from one study were evaluated, then the nondetected concentrations are equal to half the reported detection limit. For this scenario, the uncertainty in the measurements is minimized since the data originated from one sampling methodology and one analytical laboratory. Hence, the true concentration is likely between the reported detection limit and zero, or approximately half.
- If data from more than one study were evaluated, then the nondetected concentrations are set equal to zero. For this scenario, the uncertainty in the measurement is compounded by different sampling methodologies and different analytical laboratories. To minimize uncertainty, nondetected values are denoted by zero.
- If ratios are evaluated, than nondetected values used in the ratio are set equal to zero to avoid a biased ratio. Note that if the nondetected value is part of the denominator, then the sample is removed from the dataset to avoid undefined ratio.

While these scenarios provide an overview of how nondetected values were handled in the geochemical evaluation, chemical-specific scenarios or particular analyses may require professional judgment to decide how nondetected values would be handled. For example, an Aroclor represents a mixture not an individual analyte; hence, nondetected Aroclor concentrations may be set equal to either zero or half the reported detection limit depending on the analysis (refer to Section 2.2.2 for more detail). Another example involves adding nondetected values and detected values. In general, nondetected values were incorporated into a summation as a zero to avoid biased totals; however, certain analyses, such as mass per unit area (MPA) calculations (Section 2.5), require nondetected values to be equal to half the reported detection limit. Details on chemical-

specific nondetected values are also provided in Section 2.2.2, Section 2.2.3, and Section 2.5.

2.2.2 DOWNCORE SEDIMENT PROFILES

Cesium-137 (Cs-137), an important parameter for the interpretation of core records with respect to time, was measured in 135 locations in the Lower Passaic River during 1991, 1992, 1993, and 1995. Due to both natural and anthropogenic causes, not all cores with Cs-137 data can be used to document changes in historical contaminant concentrations over time (*i.e.*, depositional history) with an acceptable accuracy. Of the 135 Cs-137 sampling locations, 14 sampling locations were identified as having interpretable Cs-137 profiles, consistent with the known input of Cs-137 to the region. (These 14 locations are part of the TSI 1995 dataset, which are available in the project database.) Table 2-4 provides information on the 14 sampling locations, while Figure 2-1 maps the locations on the Lower Passaic River.

Table 2-4: Locations of Complete Cesium-137 Profiles

Tierra Solutions, Inc. Location	X-Coordinate	Y-Coordinate	River Mile	Depth of Sediment Sampled (feet) [a]
TSI 209	598198	691320	1.46	5.5
TSI 222	595563	695459	2.65	13.6
TSI 228	593188	695244	3.10	11
TSI 230	593149	695455	3.10	7.2
TSI 286	593249	695021	3.10	5.6
TSI 232	592028	694972	3.33	6
TSI 235	591151	694213	3.55	7.2
TSI 241	589595	692519	4.01	11.9
TSI 248	587218	692459	4.47	14.8
TSI 251	586182	693013	4.70	8.5
TSI 253	585542	693974	4.92	5.5
TSI 272	585243	701014	6.27	10.5
TSI 296	585527	701638	6.40	5.6
TSI 275	585643	702116	6.49	7

a: Depth represents bottom of last core segment sampled for either radiological or analytical samples. This depth does not necessarily represent the total coring depth since segmentation of the core extended only to the 1940 time horizon [Field Sampling Plan (Tierra Solutions, Inc., 1995a)].

Using these 14 cores, downcore sediment profiles were constructed for each contaminant of interest. Each profile was constructed following geochemical conventions with depth as the vertical axis and concentration as the horizontal axis. Points on the profile represent the analyte concentration for a given core segment plotted at the depth corresponding to the segment midpoint. Cs-137 is plotted in units of picocuries/gram (pCi/g) with nondetected values of Cs-137 plotted as zero to aid the dating of the sediment core. Corresponding analyte concentrations are in units of microgram per kilogram of sediment (μg/kg) unless otherwise noted. Nondetected values (laboratory qualifiers containing a U) are plotted as half the reported concentration, unless otherwise noted, and marked as a solid symbol in the downcore profiles. Detected concentrations are marked as open symbols in the profiles. All rejected concentrations (laboratory qualifier of R) were removed from dataset before plotting. For metals, the urban background concentration is also plotted on the graph. These background concentrations

represent urban soils since relatively little data are available to describe background sediment levels for the Lower Passaic River. More appropriate background values may be considered as the geochemical and risk assessment analyses continue.

In general, database queries were the same for each of the examined contaminants; however, some chemical classes required additional data manipulations, as described below:

Polycyclic Aromatic Hydrocarbons (PAH): "Total PAH" was defined as the sum of the 16 PAHs listed on the USEPA priority pollutant list (Table 2-3). High-molecular weight PAH (HMW PAH) was defined as the sum of the 10 PAHs listed on the USEPA priority pollutant list that that have a molecular weight greater than 202 gram/mole (Table 2-3). For both of these summations, nondetected values (marked with a laboratory qualifier containing a U) were set equal to zero, and sediment samples that were not analyzed for all compounds were excluded from the analysis to avoid biased low totals.

PAH compounds have been observed to exhibit different levels of toxicity. The USEPA *Guidelines for Carcinogen Risk Assessment* identified seven PAHs as "probable human carcinogens," or Group B2 compounds (USEPA, 1986). Commonly, toxicity is expressed as a toxic equivalent quotient (TEQ) where individual compounds within a sample are multiplied by a toxic equivalent factor (TEF) and the results are summed. The TEF expresses the toxicity of each compound as a fraction of the toxicity attributed to the most toxic compound (Van den Berg *et al.*, 1998). However, since TEFs have not been formally defined for the Group B2 PAHs, "estimated order of potential potency" values were used to estimate a Total PAH concentration relative to benzo[a]pyrene (USEPA, 1993). For this benzo[a]pyrene equivalence, nondetected results were equal to half the reported detection limit so that weighing factors would not be canceled out. The following factors were applied to calculate a benzo[a]pyrene equivalence concentration (the remaining PAH compounds had a weighing factor equal to zero):

- Benzo[a]pyrene   1
- Dibenz[a,h]anthracene   1
- Benzo[b]fluoranthene   0.1
- Benz[a]anthracene   0.1
- Indeno[1,2,3-c,d]pyrene   0.1
- Benzo[k]fluoranthene   0.01
- Chrysene   0.001

Pesticides: Five pesticides were examined in this geochemical evaluation: aldrin, dieldrin, Total Chlordane, Total Endrin, and 1,1,1-trichloro-2,2-bis(4-chlorophenyl)ethane (DDT). For aldrin and dieldrin, detectable concentrations are plotted in units of µg/kg. Nondetected values (lab qualifier containing a U) are plotted as half the reported concentration. Total Chlordane represents the sum of the cis-isomer and trans-isomer. If one of these isomers were not analyzed, then Total Chlordane is not plotted to avoid a biased low total. Nondetected values (lab qualifier containing a U) are included in the Total Chlordane summation as zero. Total Endrin represents the sum of endrin ketone,

endrin, and endrin aldehyde. If one or more of these analytes were not analyzed or was rejected, then Total Endrin is not plotted. Nondetected values (lab qualifier containing a U) are included in the Total Endrin summation as zero.

Total DDT represents the sum of DDT and its metabolites (whenever possible): 1,1-dichloro-2,2-bis-(p-chlorophenyl)ethane (DDD) and 1,1-dichloro-2,2-bis-(p-chlorophenyl)ethylene (DDE). To be consistent with the MPA calculations, which estimate contaminant inventory (Section 2.5), nondetected values were incorporated into the sum as half the reported detection limit.

Polychlorinated Biphenyls (PCB): "Total PCB" was defined as the sum of Aroclor 1248, Aroclor 1254, and Aroclor 1260. However, since Aroclors represent mixtures and quantification of these mixtures is dependent on the interpretation by the laboratory, the following scenarios were applied to calculate Total PCB. If all three Aroclors were nondetect, then Total PCB was calculated as half of the highest reported detection limit. If more than one Aroclor was detected, then the remaining nondetected values were set equal to zero, and Total PCB was calculated as the sum of Aroclors. Note that Aroclor 1242 and Aroclor 1221 were detected in less than 2 percent of the sediment samples (or 12 samples), but these Aroclors were excluded from the summation to maintain consistency in the representation.

2,3,7,8-Tetrachlorinated-p-dibenzodioxin (2,3,7,8-TCDD): Downcore profiles of 2,3,7,8-TCDD were prepared as both the concentration of 2,3,7,8-TCDD as well as the ratio of 2,3,7,8-TCDD to the total tetrachlorinated dibenzodioxins (Total TCDD). Total TCDD and 2,3,7,8-TCDD as reported by TSI was measured by USEPA Method 1613 (Tierra Solutions, Inc., 1995b). An assumption was made that USEPA Method 1613 was also used in other studies for the measurement of these compounds; however, this assumption could not be verified. For the ratio of 2,3,7,8-TCDD/Total TCDD, nondetected results (laboratory qualifiers containing a U) were assigned a value of zero to avoid an estimated value for the ratio. Note that samples containing a nondetected value for Total TCDD were removed from the analysis to avoid an undefined ratio.

Three locations [TSI locations 241 (RM 4.0) and 272 (RM 6.3)] were selected to represent the Lower Passaic River from RM 1 to 7. Downcore profiles were converted to a time basis. These profiles were accomplished by first calculating a location-specific sedimentation rate (feet/year) from the Cs-137 profile, and then dividing the core-segment depths by the sedimentation rate. The ratios of 2,3,7,8-TCDD/Total TCDD were then plotted on this new axis along with the concentrations of 2,3,7,8-TCDD (μg/kg).

2.2.3   SURFACE CONCENTRATION SCATTER PLOTS

Surface concentration scatter plots for the Lower Passaic River were constructed for many of the major contaminants, representing two different time periods: 1995 and 1963. The data for 1995 were restricted to surficial sediment (defined as 0-0.5 foot) from the TSI 1995 dataset available in the project database. Analyte concentrations are in units of milligram per kilogram of sediment (mg/kg) unless otherwise noted and plotted on a logarithmic scale. Nondetected results are plotted as half the reported detection limit.

For graphing purposes, sample locations (x and y coordinates) were projected to the river centerline to determine the nearest river mile.

For the 14 locations presented in Table 2-4, interpolated 1963 concentrations were also plotted to illustrate location-specific surface concentrations in 1963. While a 1963 time horizon was identifiable in the radiological samples, the 1963 analyte concentrations had to be interpolated from the available data since the radiological samples, although from the same core, were processed at different sediment intervals than the chemical analytes. Once the peak Cs-137 depth was identified, analyte concentrations from core segments above and below the peak Cs-137 depth were obtained. The analyte concentrations in these core segments were then used to linearly interpolate an estimated 1963 concentration corresponding to the peak Cs-137 depth. The interpolated 1963 dataset was statistically analyzed using the T-test and Mann-Kendall test to characterize the population and to assess trends.

In addition to these Lower Passaic River surface concentration plots, surface concentrations for select contaminants were examined in Newark Bay, the Hackensack River, the Arthur Kill, and Kill van Kull. Surface concentrations were then incorporated into mass balances for 2,3,7,8-TCDD and mercury. For these plots, surficial sediment was defined as core segments having a core top equal to zero (no restriction on core segment bottom). Queries were designed to collect available data from 1990 to 2000. Data sources are summarized in Table 2-5.

Table 2-5: Data Source for Mass Balance Calculation

Sample Collection Year	Sponsoring Organization	Name of Study in Project Database
1990	USEPA	1990 Surficial Sediment Investigation
1991	USEPA	1991 Core Sediment Investigation
1991-1998	Tierra Solutions, Inc.	2004 Newark Bay Remedial Investigation Work Plan
1992	USEPA	1992 Core Sediment Investigation
1993	USEPA	1993 Core Sediment Investigation - 01 (March)
1993	USEPA	1993 Core Sediment Investigation - 02 (July)
1994	USEPA	1994 Surficial Sediment Investigation
1995	Tierra Solutions, Inc.	1995 Remedial Investigation Sampling Program
1995	USEPA	1995 Sediment Grab Sampling Program
1996	USEPA	1996 Newark Bay Reach A Sediment Sampling Program
1998	USEPA	1998 Newark Bay Elizabeth Channel Sampling Program
1999	USEPA	1999 Late Summer/Early Fall ESP Sampling Program
1999	USEPA	1999 Newark Bay Reach ABCD Baseline Sampling Program
1999	USEPA	1999 Sediment Sampling Program
1999/2000	USEPA	1999/2000 Minish Park Monitoring Program
2000	USEPA	2000 Spring ESP Sampling Program

2.3   SOURCE ANALYSIS

To supplement the downcore profiles and scatter plots, which show concentration trends and gradients, ratios of analytes were evaluated to identify potential sources. In general, sources create unique, identifiable relationships or signatures (sometimes called "fingerprints") among specific, source-related contaminants. No matter how far from the

source samples are collected, or how much dilution may have occurred over time (or over distance), the ratio attributable to that source is identifiable, assuming that a secondary source has not contributed another signature. The following section describes the preparation of various ratios that were examined for source analysis.

2.3.1 METAL SOURCE CHARACTERIZATION

Radar plots[4] of metal concentrations were prepared for surficial sediment samples in the Lower Passaic River (defined as 0-0.5 foot) based on the TSI 1995 dataset available on the project database. In total, nine metals were included in the analysis, representing the most commonly detected metals (Table 2-3): arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, and silver. Because the comparisons were based on the relative proportion of each metal in the sample mixture (*i.e.*, mass fraction), the samples considered were restricted to locations where all 9 metals were detected. Thus, locations containing a nondetected metal result or a rejected metal concentration were removed from the analysis. The final dataset used included 63 surface sediment locations of the available 95 locations. Analyte concentrations were plotted as a unitless mass fraction on a radar plot with logarithmic scales. Each radar plot contains the sampling locations contained in one river mile. An additional radar plot was constructed by selecting one representative sampling location per river mile.

2.3.2 DDT SOURCE CHARACTERIZATION

A ratio of DDT isomers was evaluated to characterize the potential source of DDT. This ratio was calculated as the sum of the 2,4'-series to the sum of all 6 isomers, including 4,4'-DDT; 2,4'-DDT; 4,4'-DDD; 2,4'-DDD; 4,4'-DDE; and 2,4'-DDE. For this calculation, nondetected results were assigned a value of zero. Queries were designed to extract data from 1990-2000 for sampling locations in the Lower Passaic River, Newark Bay, the Hackensack River, the Arthur Kill, and Kill van Kull.

2.3.3 PAH SOURCE CHARACTERIZATION

Potential sources of PAH compounds were examined by calculating PAH ratios in an effort to link a measured PAH mixture with an identified mixture in the literature. Note that in constructing any of the ratios described below, nondetected values (laboratory qualifier containing a U) were assigned a value of zero. This zero assignment was done to avoid confounding variance in the ratios with variance due to analytical issues and speculation as to the actual concentration for a compound below the detection limit. Three different analyses were conducted on the PAH compounds using the 1995 surface and subsurface sediment PAH data (1995 TSI dataset).

For the first analysis, the ratio of fluoranthene to sum of fluoranthene and pyrene and the proportion of high mass 4-ring to 6-ring PAH compounds to Total PAH were calculated. These ratios were selected based on the recent study by Yan *et al*. (2004) who identified four separate PAH ratios as promising indicators of PAHs sources. (Note that only two of the Yan *et al.* ratios could be constructed from the available data.)

---

[4] In a radar chart, each parameter has its own value axis radiating from the center point of the graph. Lines connect all the values in a given sample. Differences in the shape of the polygon formed by each sample suggest different contaminant mixtures.

The second PAH analysis involved double-ratio scatter plots of unsubstituted PAH compounds[5] to understand the different combustion-related sources, as suggested by Costa and Sauer (2005). The double-ratio plots included:

- Benz[a]anthracene/chrysene versus fluoranthene/pyrene
- Benz[a]anthracene/benzo[a]pyrene versus fluoranthene/pyrene
- Chrysene /benzo[a]pyrene versus fluoranthene/pyrene.

The signatures observed for different sources by Costa and Sauer (2005) were incorporated in the plots to aid in interpreting the data. In addition to the ratio comparisons of the unsubstituted PAH, the concentration of Total PAH was plotted against the ratio of fluoranthene to pyrene to understand the magnitude of PAH compounds attributable to different source categories.

The third analysis was a principal component analysis, which was performed to further investigate possible sources by identifying statistically significant PAH patterns in the data. A principal component analysis is a statistical method that computes linear combinations of the variables (*i.e.,* the individual PAH compound results) and identifies those combinations that can explain the majority of the variance of a dataset. To eliminate the influence or dominance of individual compound concentrations, values were normalized by rendering concentration into fractions of the Total PAH for the sample. Nondetected concentrations (laboratory qualifiers containing a U) were assigned zero values. Additionally, the correlation matrix (also known as z-scoring), which scales the data to zero mean and unity standard deviation, was used for the analysis. The principal component analysis was conducted using Statgraphics Plus 5.1[TM], and only the principal components with eigenvalues less than 1.0 were retained in the analysis.

2.4   GEOSTATISTICAL VOLUME CALCULATION

In addition to estimating contaminated sediment volume based on historical core chemistry, fine-grained sediment volume estimates were generated from data gathered during the 2005 sediment core program conducted by Malcolm Pirnie, Inc. These cores, totaling 76, include cores from the geophysical survey (Aqua Survey, Inc., 2005) and the high-resolution coring program conducted by Malcolm Pirnie in September to October 2005. For each boring, the thickness of recent (*i.e.*, industrial era) fine-grained deposits were identified based on grain size classification, sediment texture, color, and associated field notes. Table 2-6 summarizes sediment textures that were classified as recent, fine-grained deposits for this evaluation.

---

[5] Unsubstituted PAH compounds are those compounds with no appending alkyl groups, such as a methyl or ethyl groups. For example, naphthalene is an unsubstituted PAH compound whereas 2-methyl naphthalene is a substituted PAH compound.

Table 2-6: Classification of Sediment in Boring Logs

Sediment Classified as Recent, Fine-Grained		Sediment NOT Classified as Recent, Fine-Grained	
Color	Sediment Texture	Color	Sediment Texture
Dark Brown	Silt	Dark Brown-Black	Silty Fine Sand
Dark Gray	Silt	Brown	Silt
Gray	Silt	Brownish Gray	Silt
Gray	Clayey Silt	Grayish Brown	Clay
Black	Silt	Reddish Brown	Silt
Olive Brown	Silt	Reddish Brown	Clayey Silt
Dark Gray	Clay	Reddish Brown	Clay
Gray	Clay	Reddish Gray	Clayey Silt
-	Organic leaf material/soil with fine Sand and Silt	-	Poorly Graded Sand with Silt
-	Peat	-	Poorly Graded Sand with Silt (underlain with gray silt)
Dark Brown-Black	Sandy Lean Clay	-	Silty Sand with Gravel
		Brownish Gray	Sandy Silt with Gravel

2.4.1 AVERAGE DEPTH APPROACH

A simple average-depth approach was applied to estimate the volume of recent, fine-grained sediments. In this approach, the geotechnical borings locations were superimposed on the silt classification zone based on side-scan sonar interpretation (Aqua Survey, Inc., 2005). As a result, 45 of the 76 borings were identified as lying within the silt boundary. Then, the average thickness of recent, fine-grained sediment was calculated for each silt polygon (which extend from RM 0 to 15). The volume of sediment in each polygon was calculated as the area of the polygon multiplied by the average thickness observed in the geotechnical borings within the polygon. The total volume of recent, fine-grained sediments equals the sum of all these polygon volumes.

2.4.2 INTERPOLATED DEPTH APPROACH

Thicknesses of the deposits (76 data points) were imported into Groundwater Modeling Systems (GMS) 5.1 software as a two-dimensional scatter point dataset along with the silt and silt/sand classification zones derived from the side-scan sonar survey (Aqua Survey, Inc., 2005). These sediment classification zones represented boundaries for the volume estimate. It was assumed that recent, fine-grained deposits do not exist in areas classified by side-scan sonar as coarse material. Zero values were added to the dataset at the edge of the silt/sand boundary along each data transect to force the thickness to zero at the boundary. The addition of zeros was necessary to constrain the interpolation since it was assumed that beyond the silt/sand boundary, the thickness was zero and that a vertical boundary existed at the silt/sand boundary.

Separate two-dimensional grids containing 100-foot cells were generated to encompass RM 0 to 6 and RM 6 to 15 (silt and silt/sand sediment texture do not extend beyond RM 15). Independent calculations were necessary to avoid long computational time due to the small grid size. RM 6 was selected as the dividing line because a natural break in the sediment texture and sedimentation rates appears at this location. The thickness of

recent, fine-grained deposits was then interpolated using the Kriging method in GMS with the parameters listed in Table 2-7. The interpolation resulted in a series of contours, representing sediment thickness.

Table 2-7: GMS Kriging Parameters

Parameters for RM 0 to 6 Analysis		Parameters for RM 6 to 15 Analysis	
Experimental Variogram	Model Variogram	Experimental Variogram	Model Variogram
Lags: 6	Nugget: 0.05	Lags: 6	Nugget: 100
Unit lag separation distance: 5,000	Contribution: 36,500	Unit lag separation distance: 4,000	Contribution: 15,800
Lag tolerance: 2,500	Range: 5,300	Lag tolerance: 2,000	Range: 5,300
Azimuth Angle: 0		Azimuth Angle: 0	
Half window Azimuth tolerance: 90		Half window Azimuth tolerance: 90	
Azimuth Bandwidth: 6,000		Azimuth Bandwidth: 6,000	

The contours were converted to a two-dimensional scatter point dataset to assign a thickness value to each of the grid cell. For each silt/sand area (defined by the silt/sand boundary), an average thickness was calculated by averaging the grid-cell values corresponding to that particular area. The volume of recent, fine-grained deposits was then calculated by multiplying the average thickness by the respective area, and summing the calculated volume results. The total volume for RM 0 to 15 (units of cubic yards) is a summation of the two independent analyses for RM 0 to 6 and RM 6 to 15.

2.5   MASS PER UNIT AREA CALCULATIONS

A MPA value for a contaminant represents a local estimate of the total contaminant mass in the sediment at each core location. These location-specific calculations are expressed as mass per square meter of area (*e.g.*, g/m^2). The local (individual core) estimates are subsequently integrated to estimate the total contaminant mass in the sediments over a selected area. MPA was calculated for select contaminants using the following formula (note that additional information on the MPA calculations is provided in Appendix A):

$$MPA = \sum_{i=1}^{no.\,core\,segments} Conc_i \times \rho_i \times l_i$$

where: $Conc_i$ =   Concentration in core segment i
              ρ_i =   Dry bulk density of core segment i
              l_i =   Length of core segment i

Contaminants examined in the MPA evaluation included mercury, 2,3,7,8-TCDD, Total DDT, and Total PCB. Historical data included sediment cores collected in 1991, 1993, and 1995 from the Lower Passaic River. Table 2-8 lists the data sources used in this evaluation.

Table 2-8: Data Sources for MPA Calculations

Analyte	Sample Collection Year / Sponsoring Organization	Name of Study in Project Database
Total DDT	1991/USEPA	1991 Core Sediment Investigation
	1993/USEPA	1993 Core Sediment Investigation - 01 (March)
	1993/USEPA	1993 Core Sediment Investigation - 02 (July)
	1995/Tierra Solutions, Inc.	1995 Remedial Investigation Sampling Program
	1995/USACE	1995 USACE Minish Park Investigation
2,3,7,8-TCDD	1991/USEPA	1991 Core Sediment Investigation
	1993/USEPA	1993 Core Sediment Investigation - 01 (March)
	1993/USEPA	1993 Core Sediment Investigation - 02 (July)
	1995/Tierra Solutions, Inc.	1995 Remedial Investigation Sampling Program
Mercury	1991/USEPA	1991 Core Sediment Investigation
	1993/USEPA	1993 Core Sediment Investigation - 02 (July)
	1995/Tierra Solutions, Inc.	1995 Remedial Investigation Sampling Program
	1995/USACE	1995 USACE Minish Park Investigation
Total PCB	1991/USEPA	1991 Core Sediment Investigation
	1993/USEPA	1993 Core Sediment Investigation - 01 (March)
	1993/USEPA	1993 Core Sediment Investigation - 02 (July)
	1995/Tierra Solutions, Inc.	1995 Remedial Investigation Sampling Program

Sections 2.5.1, 2.5.2 and 2.5.3 describe the derivation of the parameters used in the MPA calculations and the classification of cores. The resulting MPA values were then delineated to estimate total contaminant mass and sediment volumes, which is discussed further in Section 2.5.4, by multiplying the MPA value by a selected area.

2.5.1 CORE SEGMENT CONCENTRATION

Queries were designed to extract contaminant concentrations for each core segment within a core. Rejected values were excluded from the calculations while nondetected results were assigned a value equal to half the reported detection limit to avoid a biased low sediment inventory. Duplicate data pairs were averaged to produce one concentration value per core segment. Mercury and 2,3,7,8-TCDD concentrations were incorporated into the formula as they are reported in the database, after the corrections for rejected, nondetected, and duplicate pair results. Total PCB and Total DDT represent the same summations used in the downcore profiles (refer to Section 2.2.2).

After compiling the available data, concentrations associated with missing core segments or rejected results were linearly interpolated from the available concentration located in adjacent core segments. (The interpolation was based on the midpoints of each of the segments.) Missing values in the uppermost layer of the core were simply assigned the value in the layer below. If a missing concentration occurred in the bottom core segment, then this core segment was excluded from the MPA calculation. However, for Total DDT and Total PCB concentrations, which involved the sum of three parameters, if one parameter was detected in the bottom core segment, then the sum equaled the detected concentration plus the concentrations of the missing parameters from the overlying segment. If all three parameters in the segment were missing, then the core segment was excluded from the MPA calculation.

2.5.2 SEDIMENT CORE CLASSIFICATION

In addition to calculating MPA values, concentration data were used to classify the sediment inventory at each core location where the vertical extent of contamination was established. Cores were classified into three groups for each of the four contaminants examined:

- Contaminant with bottom concentration below reporting limit.
- Contaminant concentration decreasing at depth.
- Contaminant concentration increasing at depth.

Note that since the four contaminants were examined independently, a given core location may be classified differently for each contaminant because of differences in depositional history, proximity to major sources, and sensitivity in analytical procedures. For example, a core may be classified in the first category for Total PCB and 2,3,7,8-TCDD, but be classified in the second category for Total DDT, and then classified in the third category for mercury.

A core defined as "contaminant bottom concentration below reporting limit" represents a core where the concentration in the bottom segment (or segments) is less than or equal to the analyte detection limit or background levels (*i.e.*, the analyte-specific criterion). This definition identifies those cores where the coring device penetrated deep enough into the sediment bed to capture the thickness of contaminated sediment and the bottom of the core is located uncontaminated sediment. The depth of contamination in this instance equals the bottom of the first core segment (viewing from the bottom-up) where the concentration first exceeds the analyte-specific criterion. In contrast, the other two categories pertain to cores where a concentration in the bottom segment is greater than the analyte-specific criterion. This condition indicates that during core collection, the coring device did not penetrate into uncontaminated sediment, and thus, additional contaminated sediments are likely to lie below the collected core length.

The latter two core categories ("contaminant concentration decreasing at depth" and "contaminant concentration elevated or increasing at depth") represent two different levels of uncertainty with respect to the contaminant inventory and the actual depth of contamination. The category of "contaminant concentration decreasing at depth" was identified as those cores whose bottom-most concentration was less than 50 percent of the maximum concentration in the core[6]. In this instance, the data suggest that most, although not all, of the contaminant inventory at the sampling location has been captured by the core. The actual depth of contamination is not expected to extend much beyond the core bottom; however, a precise depth of contamination and contaminant inventory cannot be calculated. Meanwhile, the category "contaminant concentration elevated or increasing at depth" possesses the most uncertainty on the depth of contamination. In this case, the bottom-most concentration is greater than 50 percent of the maximum

---

[6] The division on "incomplete" cores into two categories is based on comparing the bottom-segment concentration to the maximum concentration in the core. Since duplicate precision is approximately 30 percent, then concentration changes less than 50 percent were considered not necessarily significant for core classification.

concentration in the core. (Note that in many of these cores the maximum concentration was located in the bottom-most segment.) As a result, the inventory and depth of contamination are poorly known since concentrations may continue to increase with depth before ultimately declining. To estimate contaminant inventory, initial calculations defined the depth of contamination as the bottom of the core for both of these categories ("contaminant concentration decreasing at depth" and "contaminant concentration elevated or increasing at depth"). Subsequent analyses then extrapolate the depth of contaminant in order to estimate the contaminant inventory (Section 5.2.2).

Core classification was dependent on the concentration in the bottom core segment relative to an analyte-specific criterion. This criterion was intended to represent the contaminant concentrations in uncontaminated sediment, or background concentrations. However, analytical procedures are limited in their ability to measure background concentrations with confidence. For example, background concentrations that would be determined detectable by one method/laboratory could be determined nondetectable by another method/laboratory. As a result, the analyte-specific criterion was defined after evaluating both background levels and detection limits. Histograms were generated showing the distribution of detected concentrations and nondetected values (refer to Appendix A). Based on these histograms and background levels, a criterion was selected at a threshold that included most detected concentrations and excluded most nondetected values. Table 2-9 summarizes the analyte-specific criterion.

Table 2-9: Summary of Analyte-Specific Criteria for Core Classification

Analyte	Approximate Background (μg/kg)	Selected Criteria (μg/kg)	Percent Nondetected Values Below Criteria [a]	Percent Detected Values Below Criteria [a]
Mercury	200 [b]	200	75 percent	5.0 percent
2,3,7,8-TCDD	0 [c]	0.002	95 percent	2.0 percent
Total PCB	0 [d]	125	95 percent	2.5 percent
Total DDT	0 [d]	10	95 percent	2.5 percent

a: Refer to Appendix A for histograms
b: Bopp *et al.*, 2006 reference for background mercury concentrations
c: Analytical methods cannot detect background levels of 2,3,7,8-TCDD; assume zero as background concentrations.
d: Both Total PCB and Total DDT are man-made compounds and do not occur naturally in the environment; assume zero as background concentrations.

2.5.3   ESTIMATION OF DRY BULK DENSITY BY CORE SEGMENT

The dry bulk density parameter in the MPA calculation converts concentration from units of mass per sediment mass to units of mass per sediment volume. While dry bulk density values were measured in 1995, information was not available to connect these density values to individual sediment core samples. Assuming that the Lower Passaic River sediment density has not changed significantly over the past 10 years, data from the 2005 geophysical survey (Aqua Survey, Inc., 2005) were used to complete the MPA calculations. Based on the grain size analyses (40 samples), a dry bulk density value was assigned to each sediment classification as derived from the side-scan sonar survey (Aqua Survey, Inc., 2005). Histograms were generated showing the distribution of the grain size 50th percentile dry bulk density for different sediment texture class (refer to

Appendix A). Dry bulk density values were then applied to the historical cores based on their plotted locations within the sediment textures as classified by Aqua Survey, Inc. (2005).

2.5.4   LENGTH OF CORE SEGMENT

Because coring methodologies differed among the historical studies, core segment lengths also varied. Moreover, while some sediment cores had continuous segmentation from the top to the core bottom, other cores had discontinuous segmentation. For example, one discontinuous core located at RM 4.87 collected by the USEPA in 1991 had the following segmentation: 0-0.17 feet, then 1.5-1.67 feet, and then 2.67 to 2.83 feet. (Note that rejected values were also a cause for discontinuous cores.) As noted previously, concentrations for the missing core segments were interpolated linearly from the available concentrations located both above and below the missing segment. Discontinuous sediment cores, which had concentrations above the criteria noted in Table 2-9 but contained less than 4 core segments, were removed from further MPA evaluation to avoid interpolating a concentration from another interpolated value.

2.5.5   MASS OF CONTAMINANT AND VOLUME OF CONTAMINATED SEDIMENT

Estimates of contaminant mass in the Lower Passaic River (RM 0.9 to 7) were generated by integrating the individual MPA values (determined for each core) over a select area of influence. These areas of influence were arranged so that each area was occupied by one coring location and restricted to one sediment texture [as interpreted by the side-scan sonar survey (Aqua Surveys, Inc., 2005)]. For example, cores located in silt zones were assigned to areas bounded within the silt zones whereas cores located in sand zones were assigned to areas bounded within sand zones. For this evaluation four sediment textures were recognized: silt, silt/sand, sand, and coarse material. The "coarse material" sediment texture included both the rock and rock/sand classification zones as interpreted by the side-scan sonar survey (Aqua Surveys, Inc., 2005) because the areal extent of the rock and rock/sand zones was limited and because the number of coring locations within these zones were limited.

The construction of areas of influence, or polygons, was accomplished by using a Thiessen polygon[7] procedure. Polygonal declustering often successfully corrects for irregular sample coverage and provides a means to integrate sample results when complicated numerical methods are not applied. As noted above, each polygon was assigned to one data point, or coring location, and was constrained to one sediment texture. Because of the scarcity of data in some areas, some locations were assigned to more than one polygon (but the condition of one point per polygon still holds). Area assignment made in this manner create an area-weighted sum, which reduces bias due to closely spaced sampling in one section of the river versus other more sparsely sampled sections of the river. The area-weighed mass of contaminant was calculated from the MPA values (MPA_i) and the area of their corresponding polygons ($Area_i$) as follows.

---

[7] Thiessen (Voronoi) polygons define individual areas of influence around each set of points. Thiessen polygons are polygons whose boundaries define the area that is closest to each point relative to all other points. They are mathematically defined by the perpendicular bisectors of the lines between all points.

$$Total\ Mass = \sum_{i=1}^{No.of\ cores} MPA_i \times Area_i$$

Volume of contaminated sediment was calculated from the individual core lengths (L_i) and the corresponding area of the polygon as follows:

$$Total\ Volume = \sum_{i=1}^{No.of\ cores} L_i \times Area_i$$

Finally a volume-weighted average concentration was obtained from the quotient of the total contaminant mass and the volume of contaminated sediments. These calculations were repeated for each of the four contaminants since each contaminant is represented by a unique combination of cores, concentrations, and depths of contamination. Subsequent calculations were then performed with extrapolated core length on incomplete core to estimate a total inventory of contaminant mass and volume.

3.0   SEDIMENT TRANSPORT

The following section discusses the results of the bathymetric comparisons and the sedimentation rate calculations (refer to Section 2.1 for methodology). These results are used to evaluate the annual solids accumulation and sedimentation rates in the Lower Passaic River. The discussion then continues and presents the first of two solids mass balance for the system that are estimated in this geochemical evaluation. Results are presented in tabular format within the text while figures are attached to the document.

3.1   ANNUAL SOLIDS ACCUMULATION

Historical bathymetric surveys were evaluated to calculate an annual solids accumulation for the Lower Passaic River (RM 0.9 to 7). In the first evaluation, all available historical surveys (1989 through 2004) were considered in a series of 10 comparisons (refer to Table 2-2). Annual solids accumulation ranged from a loss of 166,000 cubic yards (representing a year of net erosion) to a gain of 144,000 cubic yards (representing a year of net deposition). The results are presented in Table 3-1 and in Figure 3-1 (blue line) along with the uncertainty in the calculation[8].

Table 3-1: Annual Accumulation (1989-2004)

Time Period	Rounded Annual Accumulation (cubic yards) [a]
1989-1995	16,800 [b]
1995-1996	144,000
1996-1997	-23,100
1997-1998	47,200
1998-1999	47,200
1999-2000	60,600
2000-2001	60,600
2001-2002	-166,000
2002-2003	99,800
2003-2004	99,800

a: Uncertainty = ±36,000 cubic yards
b: 16,800 cubic yards represents the average annual accumulation for 6 years; the total accumulation from 1989-1995 is 100,800 cubic yards.

An initial observation of this bathymetric comparison suggests that the Lower Passaic River (RM 0.9 to 7.0) is dynamic, experiencing both years of net erosion and years of net deposition. The largest sediment transport events were roughly equivalent to 2 inches gain or loss of sediment from the river bottom; however, most years exhibited a net gain of sediment. On closer inspection, however, the uncertainty associated with the 1996

---

[8] The volume is associated with a 1-inch uncertainty on the mean elevation. This uncertainty on the mean difference between survey elevations is based on professional judgment, recognizing that the uncertainty on one measurement (±6 inches) is significantly reduced for the mean, as the number of observations increases. The selection of a 1-inch uncertainty also recognizes that much of the uncertainty may originate from the vertical control of the survey.

through 2001 data suggest that the annual accumulation is often close to, or within the uncertainty of the measurements. In addition, large swings in accumulation estimates are coincidently associated with changes in surveying company, suggesting that misalignment in transects and/or survey accuracy may be contributing to additional uncertainty in the calculation. For example, the net loss of solids of 166,000 cubic yards was calculated by comparing the 2001 survey by TSI and the 2002 survey by TVGA Consultants. While a net loss of solids may have occurred during this time period, the actual uncertainty around this number is likely greater than the calculated uncertainty of 36,000 cubic yards.

In an effort to reduce the uncertainty associated with the misalignment of transects and disparate methodologies, a second bathymetric comparison was completed using the most consistently aligned surveys, most of which were collected by TSI (refer to Table 2-1 and Table 2-2). The results are presented in Table 3-2 and in Figure 3-1 (green line) along with the uncertainty in the calculation.

Table 3-2: Annual Accumulation (1995-2004)

Time Period	Rounded Annual Accumulation (cubic yards) [a]
1995-1996	165,000
1996-1997	-45,200
1997-1998	65,400
1998-1999	65,400
1999-2000	68,800
2000-2001	68,800
2001-2002	5,870
2002-2003	5,870
2003-2004	5,870

a: Uncertainty ±46,000 cubic yards

Again, the overall observation of this comparison is that the Lower Passaic River (RM 0.9 to 7.0) is dynamic. Hence, the conclusions drawn from the first evaluation (Table 3-1), which incorporated the ten historical bathymetric surveys, are the same as the conclusions drawn from the second evaluation (Table 3-2), which incorporated a subset of surveys with aligned survey transects. The large swing estimate in 2001-2002 is absent in this comparison; however, the uncertainty associated with the low solids accumulation between 2001 and 2004, suggest that erosion probably occurred. The erosion event in 1996-1997 appears to be significant in this evaluation even though the uncertainty associated with this comparison is greater than the 1989-2004 comparison. Note that the area associated with 1995-2004 comparison is greater than the area associated with the 1989-2004 comparison, thus, corresponding to a greater uncertainty.

3.2   SEDIMENTATION RATES

To further evaluate the 1995-2004 comparison, the average sedimentation rate per quarter river mile was calculated (Figure 3-2). Each symbol in the Figure 3-2 legend represents a comparison relative to the 1995 survey; hence, the 1995-1996 comparison (red circles) possesses the largest sampling uncertainty is associated with the bathymetric-sounding

equipment. As the sampling uncertainty decreases in the other comparisons that represent larger time periods, the average sedimentation rate converges on 1-2 inch/year; however, sedimentation rates continue to vary along the river and over time. A low-depositional or an erosional environment occurs at RM 4 and 6 while a high-depositional environment exists at the mouth of the Lower Passaic River.

Heterogeneous sedimentation rates in the Lower Passaic River were previously noted in the *Preliminary Geochemical Evaluation* (Section 3.4; Malcolm Pirnie, Inc., 2005). Similar results are presented in Figure 3-3, which maps sedimentation rates based on the 1995-2001 comparison along with location-specific sedimentation rates calculated using Cs-137[9] [refer to Section 4.4.1 and the *Preliminary Geochemical Evaluation* (Malcolm Pirnie, Inc., 2005) for further discussion on the estimation of sediment deposition rates from cores]. A general consistency exists between the mean core-based sedimentation rates and the bathymetric-based sedimentation rate; however, the datasets do not perfectly align. Figure 3-4 presents the average sedimentation rate per quarter river mile based on location-specific core data (red line) and the bathymetric-based data (blue line; same data as shown in Figure 3-2). Except at the mouth of the river, the two datasets show similar trends and similar sedimentation rates even though the data were generated from two independent methods. As expected, the difference between the two datasets decreases when more cores were available for analysis.

To summarize, the comparison of sedimentation rates suggest that the Lower Passaic River from RM 0.9 to 7 is dynamic, experiencing years of net deposition and years of net erosion. Spatially, sedimentation rates are heterogeneous with depositional environments occupying the same river mile as erosional environments. Annual accumulation values and average sedimentation rates suggest, however, that the Lower Passaic River (RM 0.9 to 7) is primarily depositional over the period of record, especially the mouth of the river. This depositional environment is coincidental with strong concentration gradients observed for six chemicals across the Lower Passaic River and into Newark Bay (HydroQual, Inc., 2005a). In this study, surface sediment concentrations (defined as 0 to <8 inches; 1990 to 2000) were averaged and plotted versus linear distance for the Lower Passaic River and Newark Bay. The average concentration of octa-chlorinated dibenzodioxin decreased by a factor of 2.5 between the mouth of the Passaic River to Newark Bay; PCB congener PCB77 decreased by a factor of 3.5; pyrene and benzo[a]pyrene decreased by a factor of 4; PCB153 decreased by a factor of 5; and 2,3,7,8- TCDD decreased by a factor of 15. It must be considered, however, that not all solids settle in the lower reaches of the Passaic River, some contaminated sediments are transported into Newark Bay and potentially beyond.

3.3   MASS BALANCE OF SOLIDS

Sediment transport in the Hudson-Raritan Estuary has been addressed in various studies, including work by Suszkowski (1978) and by Konsevick (1991). Recent work by Lowe

---

[9] Sedimentation rates based on the 1995-2001 comparison were originally presented in Figure 23 of the Preliminary Geochemical Evaluation. Figure 23 also included location-specific sedimentation rates calculated from both Cs-137 and lead-210. For this evaluation, the depositional rates for lead-210 data were excluded due to their higher level of uncertainty.

et al. (2005) provides additional information on solids load and the fate of contaminants. Their work suggests that the solids load to the Lower Passaic River, including the flow over the Dundee Dam as well as the tributaries of the Lower Passaic River, is roughly 79,000 cubic yard/year. This study, however, does not consider solids deposition in the Lower Passaic River. In an effort to complete this calculation and to estimate the solids load at the mouth of the Passaic River, the 1989 and 2004 bathymetric surveys were compared from RM 0 to 15. (These two surveys were compared because bathymetric data extended to RM 15; however, because of the 15 year time span between surveying events, any extreme depositional or erosional events are averaged-out.) This comparison yielded an annual solid accumulation[10] of 67,000 cubic yards for RM 0 to 15. This annual accumulation is equivalent to approximately 1 inch of sediment accumulation over the Lower Passaic River bottom (RM 0 to 15). However, approximately, 90 percent of this accumulation (or 59,000 cubic yards) occurs in RM 0 to 7, which is roughly equivalent to 1 and a third inch/year. Were the entire annual accumulation to occur in RM 0 to 7, this accumulation would yield an annual deposition rate of roughly 1 and a half inch/year.

The difference between the Lowe *et al.* value and the bathymetric net deposition value is approximately 12,000 cubic yard/year, representing the annual solids load from the Lower Passaic River to Newark Bay. This calculation contradicts the conclusion by Huntley *et al.* (1991), who examined select radiological data and concluded that sediments from the Lower Passaic River were not being transported to Newark Bay. Table 3-3 provides a revised mass balance of solids for Newark Bay considering the loss of solids in the Lower Passaic River due to deposition (values for the Hackensack River, combined sewers/water treatment plants, and atmospheric deposition were taken from the Lowe *et al.* 2005 study).

Table 3-3: Estimated Mass Balance for Solids for Newark Bay

Source of Solids	Lowe *et al.* Mass Balance (cubic yards)	Estimated Mass Balance (cubic yards) [a]
Passaic River	79,100	12,400
Hackensack River	6,460	6,460
Combined Sewer/Water Treatment	10,500	10,500
Atmospheric Deposition	285	285
Kill van Kull	205,000	260,000
Arthur Kill	41,900	53,200

a: Based on Lowe *et al.* (2005); Balance is based on a correction for deposition in the Lower Passaic River. An alternative solids mass balance derived from chemical mass transport considerations is presented in Section 4.6.

One caveat to the solids mass balance presented in Table 3-3 is the uncertainty associated with the annual solids accumulation in the Lower Passaic River. The annual accumulation of 67,000 cubic yards represents a net deposition over 570 acres (comparisons of the 1989 and 2004 surveys from RM 0 to 15); however the uncertainty associated with this depositional volume may be large relative to the estimate. This uncertainty is compounded by the uncertainty associated with the solids load coming over

---

[10] The annual accumulation of 67,000 cubic yards represents a net deposition over 570 acres. The volume of sediment associated with a 1-inch uncertainty over the 570 acres is 77,000 cubic yards.

the Dundee Dam [79,100 cubic yards reported by Lowe *et al.* (2005)]. Nevertheless, the revised solids mass balance (Table 3-3) is an improvement over the original estimate prepared by Lowe *et al.* (2005) but is still subject to uncertainty related to the actual rate of accumulation in the Lower Passaic River.

Nevertheless, geochemical data support the conclusion of this estimated solids mass balance that a substantive portion of the solids originating from the Lower Passaic River are escaping the mouth of the river and entering Newark Bay. Once Passaic-sediments enter Newark Bay, they have the potential of being either deposited in Newark Bay sediment beds or transported throughout the Hudson-Raritan Estuary. Bopp *et al.* (1991a) showed from a sediment core collected in Newark Bay that the highest polychlorinated dibenzodioxin (PCDD) concentration occurred in sediments dating from the 1950s and 1960s. This peak concentration coincides with the peak production and discharge of PCDD into the Lower Passaic River during the 1950s and 1960s. Similar sediment profiles were also generated for the Lower Passaic River (Section 4.3.4). To produce similar profiles in the Lower Passaic River and Newark Bay, Passaic-contaminated sediment must be transported from the Lower Passaic River to Newark Bay. Hence, geochemistry may present an alternative approach for accounting for solids deposition in the Lower Passaic River and the construction of a more accurate solids mass balance (Section 4.6).

3.4   SEDIMENT TRANSPORT AND DEPOSITION SUMMARY

The following conclusions and observations summarize the sediment transport and deposition section:

- Sediment accumulation in the Lower Passaic River is dynamic with some relatively large swings in annual accumulation as suggested by a series of bathymetric surveys. Annual sediment deposition averaged approximately 70,000 cubic yard/year between 1989 and 2004 (RM 0 to 15), which is roughly equivalent to one inch of sediment accumulation over the Lower Passaic River bottom (RM 0 to 15). Approximately 90 percent of this accumulation occurs in the RM 0 to 7. Area-averaged deposition rates were consistent with those rates obtained from dated sediment cores collected from the same areas.
- The largest sediment transport events were roughly equivalent to 2 inches of loss or gain of sediment although most years exhibited a net gain of sediment.
- A detailed examination of sediment deposition rates in the Lower Passaic River (RM 0.9 to 7) indicates a high degree of spatial heterogeneity with local rates varying from about -6 inch/year of erosion to about +8 inch/year of deposition. However, annual accumulation values and average sedimentation rates suggest that the Lower Passaic River (RM 0 to 7) is primarily depositional with the highest deposition rates occurring in RM 0 to 1.
- While the Lower Passaic River is experiencing a net deposition of sediment for the period examined, a solids mass balance indicates that upriver solids are transported through the Lower Passaic River into Newark Bay, and potentially beyond. Estimates suggest that 20 to 50 percent of the upriver solids are eventually transported out of the Lower Passaic River.

4.0 CONTAMINANTS IN THE LOWER PASSAIC RIVER

The following section discusses the interpretation of downcore profiles and scatter plots constructed using the 1995 TSI dataset (refer to Section 2.2 and Section 2.3 for methodology). These results are used to evaluate historical loading and to identify potential sources in the Lower Passaic River. Data from other studies on sediment concentrations from the Upper Passaic River (above Dundee Dam) are also utilized to examine potential upriver and downriver sources. Further evaluations of potential sources were completed using contaminant ratios, which enabled the characterization of some sources and source regimes. The discussion then continues with a revised solids mass balance for Newark Bay based on 2,3,7,8-TCDD concentrations and an estimated chemical mass balances for 2,3,7,8-TCDD and mercury. Results are presented in tabular format within the text while figures are attached to the document.

4.1 CONCEPTUAL MODEL OF SEDIMENT DEPOSITION AND CORING

Before beginning a discussion of the sediment core chronology results, it is useful to outline the basic concepts that form the basis for core collection and analysis. This conceptual model of sediment accumulation at a particular location underlies the interpretations described later in this section. The model is defined by the following assumptions:

- Sediment accumulation at an interpretable coring location occurs continuously over time with the greatest sediment accumulation occurring during the highest sediment transport events. Thus, a core collected from accumulated sediments preferentially represents the higher flow periods since they are generally associated with the highest sediment transport.
- Sediment accumulation is assumed to be relatively constant on an annual basis although varying seasonally with flow, so equal-length core segments represent similar time periods in ideal conditions.
- Biological stirring of the sediments occurs only minimal, avoiding the mixing of more than one or two years of deposition.
- The effects of human activities on sediment accumulation are minimal, can be documented (*e.g.*, a known dredging event), or can be inferred from discontinuities in sediment radionuclide profiles.
- Sediments which accumulate at a given location reflect the water column conditions at the time of deposition at that location (*i.e.,* the sediments are effectively a sampling of the water column suspended matter).
- At locations with datable cores, relatively little resuspension occurs relative to net sediment deposition (*i.e.*, few or no erosional events).
- Tidal mixing within the Lower Passaic River is such that suspended solids are well mixed over multiple miles prior to their deposition. Therefore, cores separated by distances of a few miles or less should be expected to yield very similar contaminant chronologies.

On this basis, a dated sediment core can be considered a record of historical water column conditions at the collection site and the surrounding area. The techniques used to verify these conditions in a core are discussed below.

4.2   ESTABLISHING SEDIMENT CORE CHRONOLOGIES

Core chronologies are established using a dating methodology, which involves the use of radionuclides as time indicators (Bopp *et al.*, 1982; and Olsen, 1979). Radionuclides can serve either as event-markers or as clocks in establishing core chronologies. To understand how radionuclides serve these purposes, it is first necessary to define radionuclides, their properties, and their origins.

A radionuclide exhibits the same chemical properties as the standard form of an element. However, the nucleus of the radionuclide is unstable and will eventually decay to a more stable state, releasing radiation in the process. The form of the radiation and its energy level are unique to the type of radionuclide. By measuring the various levels of radioactivity released by a sample, it is possible to detect the presence of many different radionuclides. Because of the magnitude of the energy released, it is often possible to detect the presence of a radionuclide at extremely low concentrations. For example, the detection limit for Cs-137 is one part in 10^{18} by weight, which is 0.60 pCi/g. Radionuclide decay is not, however, instantaneous, but occurs gradually over time in an exponential fashion. This property is characterized in terms of a half-life ($t_{1/2}$) which is defined as the time for a radionuclide concentration to decay to half of its original concentration. In general, it is difficult to detect environmental levels of a radionuclide after about five half-lives have passed (*i.e.*, when only about 3 percent of the initial concentration remains).

Radionuclides are produced by many different processes. Some are generated naturally, such as beryllium-7 and carbon-14, which are produced by solar radiation in the upper atmosphere. Lead-210 is the result of atmospheric fallout from naturally occurring radon-222. Some radionuclides are man-made, such as plutonium-239, cobalt-60, and Cs-137, which may be produced during detonation of a nuclear weapon or the generation of nuclear power. Several natural and anthropogenic radionuclides, which tend to bind to fine-grained sediments, are present in the Lower Passaic River environment. These radionuclides can be useful tracers for fine-grained sediment transport and accumulation patterns in the sediments (Olsen, 1979; Olsen *et al.*, 1981). Most of the major contaminants of the Lower Passaic River have also been shown to bind to fine-grained sediments (*e.g.,* Bopp *et al.*, 1991a). Thus, known radionuclide releases can be used to date the time of sediment deposition in the Lower Passaic River, and thereby, provide a means of examining the history of water-borne contaminant transport.

For the sediment cores of the Lower Passaic River, radionuclide chronologies were established based primarily on Cs-137. For this radionuclide, there are two major release events that result in sediment horizons of known age. The primary means of release of Cs-137 to the Passaic watershed is the atmospheric fallout that resulted from atmospheric weapons testing in the 1950s and 1960s. The earliest appearance of Cs-137 in the sediments is considered to coincide with 1954, the year in which the United States began

a major atmospheric weapons testing program. Other countries soon followed suit, leading to an atmospheric weapons test ban treaty which went into effect in 1964. However, in the year prior to the implementation of the treaty, many atmospheric tests were conducted, leading to a major release of Cs-137. This release is expressed as a Cs-137 concentration maximum in the sediments, which is assigned the year 1963. Armed with these two marker horizons, the sedimentation rate and a core chronology can be estimated for many sediment cores.

4.3   DOWNCORE PROFILES AND CONTAMINANT HISTORY

For a core to provide a useful chronology of contaminant transport over time, it must have an interpretable radionuclide chronology. The core must also have sufficient vertical resolution, so a sufficient number of core segments can be analyzed to describe the historic changes in contaminant concentration in the water column, suspended matter over the depositional period represented by the core. A review of the available core data for the Lower Passaic River yielded a total of 14 cores that met these criteria (Table 2-4). Of these cores, 12 cores presented internally consistent chronologies of contaminant histories, described in Section 4.3. However, two locations do not exhibit consistent chemical profiles (TSI locations 248 and 251), suggesting that the locations had been disturbed in the mid-1950s. [The following discussion focuses on sediment history and recent (*circa* 1995) contaminant deposition for the 14 select locations. A separate discussion is presented in Section 4.4, which focuses on surficial sediment from the larger 1995 TSI dataset.]

Downcore sediment profiles were originally presented in the *Preliminary Geochemical Evaluation* for Total DDT and 2,3,7,8-TCDD. The discussions that follow re-examine these profiles and present profiles of other contaminants to examine the history of contamination in the Lower Passaic River.[11] These contaminants include semivolatile organic compounds (SVOCs), Total PAH, pesticides, Total PCB, and metals.

4.3.1   SEMIVOLATILE ORGANIC COMPOUNDS

Downcore profiles of SVOC compounds are presented in Figure 4-1 (each plot represents one sampling location). In general, the majority of the SVOC data were nondetect; however, a few cores showed low-level detections of one or more contaminants at depth within the core. Given the limited number of detections as well as the limited spatial extent of the cores in which the contaminants were detected, it is unclear whether these detections represent local sources.

For example, butyl benzyl phthalate has a local maximum (25 mg/kg) near RM 6 with peak concentrations occurring at the 1963 time horizon. Likewise, dibenzofuran has a local maximum near RM 4 (8.5 mg/kg) with peak concentrations occurring in a horizon dated before 1963. In addition to these observed detections, a review of the 1995 TSI dataset revealed that other detected concentrations for both butyl benzyl phthalate and dibenzofuran are scattered throughout the Lower Passaic River (RM 0 to 7). Unlike these

---

[11] A re-examination of the ratio of surface contaminant concentration to Cs-137 revealed a high level of variability in the ratio. Based on this review, the most appropriate use of the Cs-137 data is to establish geochronology in sediment cores and to act as a normalizing parameter.

two compounds, 1,4-dichlorobenzene was present only at TSI location 286 (RM 3.1), which is located on a mudflat on the southern bank of the Lower Passaic River. Note that 1,4-dichlorobenzene is relatively soluble and thus is only likely to impact sediments located near a source area. An additional review of the 1995 TSI dataset revealed that the only other sampling location that showed detectable levels of 1,4-dichlorobenzene in more than one core segment was TSI location 285, which was located on the same mudflat at RM 3.3. While the spatial distribution of 1,4-dichlorobenzene is limited, the concentration of this contaminant exceeds 200 mg/kg.

Since SVOC detections are sparse, and trends are not clearly discernible, no conclusions can be made at this time on the fate of SVOCs. Hence, no further evaluations were completed on these compounds.

4.3.2 POLYCYCLIC AROMATIC HYDROCARBONS

Total PAH was present in nearly all sediment samples at nearly all depths. Total PAH concentrations in the top segment (0-0.5 foot) of sediment cores ranged from 7.5 to 28 mg/kg with an average concentration of 21 mg/kg (refer to the blue squares in Figure 4-2). The downcore segment detections remain similar to the magnitude of the surface concentration until *circa* 1950s-1960s when concentrations begin to increase with depth. In general, the maximum reported Total PAH concentration in each examined core ranged from 100-200 mg/kg. With the exception of TSI location 248[12], Total PAH concentrations did not reach a maximum value and subsequently decline to background concentrations. Rather, Total PAH concentrations reached their maximum value at the core bottom, suggesting that the collected cores were not advanced deep enough to capture the full inventory of Total PAH and that peak loading of Total PAH likely occurred prior to the 1940s, which is the deepest temporal extent of most of the dated sediment cores.

To further evaluate the PAH constituents, the concentration of HMW PAH was calculated and plotted (orange circles; Figure 4-2). HMW PAH accounted for an average of 81 percent of the Total PAH concentration (median 84 percent with a range of 33-100 percent), resulting in similar profiles for HMW PAH and Total PAH. (A further discussion of PAH source using PAH ratios continues in Section 4.5.3.) Another observation was that one HMW PAH, benzo[a]pyrene, contributed up to 16 percent of the Total PAH concentration. Note that benzo[a]pyrene, along with six other HMW PAHs, is considered probable human carcinogens (USEPA, 1986). In an effort to convert Total PAH to a benzo[a]pyrene equivalent, "estimated order of potential potency" factors published by USEPA (1993) were used to manipulate the PAH data. Downcore profiles of benzo[a]pyrene equivalence are presented in Figure 4-3. In general, these profiles

---

[12] The sediment core located at TSI location 248 may contain a discontinuity at a depth of 6-8 feet just below the Cs-137 1963 peak (discussed below in Section 4.3.6). Total PAH concentration corresponding to the 1960s time horizon (5.2 feet) is 143 mg/kg, which is similar to concentrations observed in other Total PAH profiles (Figure 4-2). It is assumed that the discontinuity at a depth of 6-8 feet removed sediments that contained peak Total PAH concentrations. The observed Total PAH profile located at a depth of 8-14 feet likely represents contamination deposited prior to the peak Total PAH loading. Hence, it is anticipated that peak Total PAH concentration, which probably existed at this location prior to the event that caused the discontinuity at 6-8 feet, was greater than 950 mg/kg (the reported concentration at 8.1 feet).

follow the same pattern as Total PAH, except the maximum concentration in each examined core is less than the corresponding Total PAH concentration by an order of magnitude.

4.3.3 PESTICIDES

Downcore profiles of pesticide compounds, including aldrin, dieldrin, Total Chlordane, and Total Endrin, are presented in Figure 4-4. Overall, these profiles display observable trends in some areas but also some inconsistencies. The Quality Assurance Project Plan (Tierra Solutions, Inc., 1995b) noted that the detection of pesticides may be complicated by potential analytical interferences, including the presence of phthalate esters and elemental sulfur. These interferences may contribute to the large number of rejected values and inconsistencies observed in the downcore profiles. In general, the following trends were observed in the pesticide dataset:

- No significant historical loadings are indicated in the aldrin data since this chemical was reported as nondetect in all 14 dated sediment cores examined. An additional review of the 1995 TSI dataset revealed that no detectable aldrin concentrations were reported at any sampling location[13].
- The analysis of Total Chlordane was hampered by a number of nondetected and rejected values. A total of five sampling locations (TSI locations 209, 222, 235, 251, and 272) displayed complete downcore profiles, which suggest that peak Total Chlordane loading (100-200 µg/kg) occurred in the 1960s. Total Chlordane was measured at other sampling locations, but trends are inconclusive because of nondetected values or missing data.
- In general, detectable levels of Total Endrin were found at almost every sampling location. However, like Total Chlordane, a number of nondetected data points hampered the interpretation. Seven sampling locations (TSI locations 209, 222, 228, 286, 235, 248, and 251) were characterized as cores with contaminant concentrations increasing at depth, which suggest that peak loading occurred prior to the 1940s. Note that Total Endrin was measured at other sampling locations, but trends are inconclusive.
- In general, detectable levels of dieldrin were detected at almost every sampling location. Dieldrin possessed the most complete set of downcore profiles among the four pesticides examined. Dieldrin profiles consistently suggest peak loading that either coincides with the Cs-137 peak or occurring below the Cs-137 peak. Maximum dieldrin concentrations range between 100 µg/kg and 200 µg/kg. However, not all sampling locations experienced such high levels.

Due to the number of rejected and nondetected values in the pesticide dataset, no further evaluations were completed on aldrin, dieldrin, Total Chlordane, and Total Endrin. Additional data collection is warranted to resolve temporal and spatial trends in these compounds.

---

[13] A search for detectable aldrin concentrations in Passaic River sediment revealed 33 records in the project database. These sediment samples (surface and sub-surface samples) were collected in 1990 through 1999 during seven different studies.

4.3.4 TOTAL DDT AND 2,3,7,8-TCDD

Total DDT and 2,3,7,8-TCDD Depth of Contamination: Total DDT and 2,3,7,8-TCDD have similar release histories as documented by Bopp *et al.* (1991a). Previously, these contaminants were examined in the *Preliminary Geochemical Evaluation* (Malcolm Pirnie, Inc., 2005) to confirm the observations of Bopp *et al.* (1991a). In that previous analysis, the text concluded that it was likely that Total DDT was present in the sediments at greater depths than 2,3,7,8,-TCDD. In the current analysis, the downcore profiles permit a review of this conclusion as well as allow for additional analysis.

In the cores examined, Total DDT and 2,3,7,8-TCDD trends with depth are very similar with most of the profiles ending with high levels of both compounds at the core bottoms (Figure 4-5). However, many, but not all of the cores, show a decline in 2,3,7,8-TCDD relative to Total DDT at the bottom of the core. The lack of a consistent decline in these cores is attributed to the short length of most cores, typically 8 feet in depth. The observations made in the *Preliminary Geochemical Evaluation* (Malcolm Pirnie, Inc., 2005) were based largely on deeper cores, where the core captured a greater span of time compared to the 14 cores examined in this evaluation. Among the cores evaluated here, those cores that do not exhibit a decline in 2,3,7,8-TCDD relative to Total DDT are each less than 8 feet in length.

Despite the shorter length for some cores, there are still several cores whose lengths were sufficient to demonstrate a decline in 2,3,7,8-TCDD relative to Total DDT. Specifically, TSI locations 232, 235, and 275 (short core sites) as well as the cores greater than 8 feet in length exhibited profiles consistent with the original analysis in the *Preliminary Geochemical Evaluation* (Malcolm Pirnie, Inc., 2005). In summary, this review confirms that Total DDT is found at greater depths than 2,3,7,8-TCDD. As a result, Total DDT can, in theory, serve as a surrogate for establishing the depth of contamination for 2,3,7,8-TCDD. However, as discussed in Section 5.2, sensitivity concerns exist for the application of Total DDT in this manner. Moreover, the analytical techniques for Total DDT used in the historical investigations are about 30 times less sensitive than those analytical techniques used for 2,3,7,8-TCDD, affecting the estimates of the depth of contamination of Total DDT relative to 2,3,7,8-TCDD. The application of Total DDT as a surrogate for 2,3,7,8-TCDD would require an improvement in the sensitivity of the Total DDT analysis.

The deepest cores in this evaluation were reviewed for consistency with the conclusions drawn by Bopp *et al.* (1991a), which relate to the history of contaminant release. In these longer cores, the Cs-137 data establish the chronology for the last 50 years of deposition. In each of these longer cores, Total DDT and 2,3,7,8-TCDD can be observed at elevated levels in the 1950s and 1960s, consistent with the observations of Bopp *et al.* (1991a). These longer cores confirm the long history of contamination for these compounds. Additionally, the maximum values occur coincident with the Cs-137 maximum, suggesting maximum discharges of Total DDT and 2,3,7,8-TCDD during this period. However, note that in more finely resolved cores, Total DDT attains a maximum concentration in the late 1940s or early 1950s. The fact that this maximum is not as

clearly evident in other cores is attributed to the relatively thick core segments of the 14 examined cores.

As part of this analysis, the Total DDT concentrations were compared with those of 2,3,7,8-TCDD as a precursor to possible ratio analysis. As seen in Figure 4-5, the concentrations in the cores do no track closely or consistently across cores or within cores, indicating that this ratio is unlikely to be useful. In light of this observation, no further analysis of the ratio was conducted.

Ratio of 2,3,7,8-TCDD to Total TCDD: In the *Preliminary Geochemical Evaluation* (Section 3.1.3.1; Malcolm Pirnie, Inc., 2005), a ratio of 2,3,7,8-TCDD/Total TCDD of 0.7 ±0.1 (±1 sigma) was calculated for the Lower Passaic River (RM 1 to 7). The consistency and uniqueness of this ratio suggests either a single source of 2,3,7,8-TCDD or, alternatively, a limited number of unique sources whose discharges are well mixed by the tidal circulation. Moreover, the calculated ratio of 0.7 ±0.1 is consistent with Chaky's observations of 0.71 in Newark Bay (Chaky, 2003), suggesting that the ratio of 2,3,7,8-TCDD/Total TCDD can be used to "fingerprint" Passaic-related PCDD contamination throughout the Lower Passaic River and Newark Bay (refer to Section 4.6.1).

Downcore profiles showing the ratio of 2,3,7,8-TCDD/Total TCDD were generated for further evaluation (Figure 4-6)[14]. Despite some variability in the data, the consistency of the ratio is quite evident with a ratio of 0.7 or more reflecting the history of production and discharge of PCDD into the Lower Passaic River. For example, at TSI location 272 (RM 6.3), the ratio is consistent from the surface to a depth corresponding to the 1970s time horizon. This homogeneity of the ratio in the upper portion of the cores likely resulted from tidal mixing and re-mixing of sediments. The ratio then increases in the 1960s as the 2,3,7,8-TCDD concentration increases two orders of magnitude. This change in the ratio and increase in concentration likely reflects the production and discharge of PCDD in the 1960s. At the bottom of the core, *circa* 1940, the ratio dramatically drops to a background signature of 0.05 or less, representing atmospheric deposition, upriver sediment transport, and sewage discharge (Chaky, 2003) and reflecting conditions before the production of (2,4,5-trichlorophenoxy)acetic acid and PCDD along the Lower Passaic River. At the same time, the 2,3,7,8-TCDD concentration also drops from 10 μg/kg to 0.02 μg/kg.

4.3.5 TOTAL PCB

Downcore profiles for Total PCB are presented in Figure 4-7. Similar to the Total PAH profiles, the Total PCB profiles do not vary spatially in the cores examined, implying that local sources of Total PCB is limited. However, unlike the Total PAH profiles that showed no conclusive peak concentration at depth, the Total PCB profiles show peak concentration in the 1960s time horizon, and then concentrations decline to nondetected values in the 1950s time horizon. Peak concentrations averaged 7.6 ±5.0 mg/kg (median

---

[14] In Figure 4-6, a ratio equal to 1 implies that the 2,3,7,8-TCDD concentration equals the concentration of the Total TCDD. Note that some ratios plotted greater than 1, which shows an uncertainty in those analytical measurements. However, these deviations are typically within 25 percent, which is well within the expected analytical precision for the analysis.

of 6.4 mg/kg) with concentrations ranging from 1.7 to 19 mg/kg. The minimal scatter in the Total PCB concentrations and in the profiles suggests that one source, possibly above the Dundee Dam, is impacting sediment in the Lower Passaic River.

It is important to note that Total PCB, as defined in Section 2.2.2, is the sum of three Aroclors (Aroclor 1248, Aroclor 1254, and Aroclor 1260) even though other Aroclors were detected in Lower Passaic River sediment. To further evaluate the Total PCB value, an evaluation was completed to investigate the contributions of each examined Aroclor to the total. The results suggest that three types of Total PCB to Aroclor 1248 correlations exist (Figure 4-8). The first situation occurs where Total PCB consists mainly of Aroclor 1248 (red plus symbol in Figure 4-8) and accounts for 53 percent of the data. The correlation between Total PCB and Aroclor 1248 for this situation is one to one. The second situation occurs where Total PCB consists of Aroclor 1248, Aroclor 1254, and Aroclor 1260 (blue circle symbol in Figure 4-8) and accounts for 46 percent of the data. A power curve was fitted to the data, which has a strong regression coefficient value of 0.91. For this group, the Aroclor 1248 percentage in the Total PCB is approximately 20 to 40 percent depending on the concentration. Lower concentrations have less Aroclor 1248 in the Total PCB. The last situation occurs where Total PCB consists of very low concentrations of Aroclor 1248 (orange cross symbol in Figure 4-8) or nondetected concentrations of Aroclor 1248 (green diamond symbol in Figure 4-8). Together, these two later groups account for approximately 5 percent of the data.

4.3.6 METALS

Downcore profiles were generated for 12 metals. Two to three profiles are presented on each plot: Figure 4-9 contains data on beryllium and thallium; Figure 4-10 contains data on antimony, mercury, and silver; Figure 4-11 contains data on nickel, barium, and lead; Figure 4-12 contains data on copper and chromium; and Figure 4-13 contains data on cadmium and arsenic. Note that for comparison the New Jersey background concentration for metals in soils is also presented in these plots (Sanders, 2003).

The first observation regarding these metal profiles is that the concentrations could be categorized into three groups: no concentration trend, concentrations increasing with depth, and concentrations increasing then declining with depth. No concentration trend was discernible for antimony, beryllium, or thallium due to a lack of detectable concentrations. Conversely, arsenic, barium, copper, lead, and nickel showed increasing concentrations with depth, suggesting that peak loadings for these metals are probably located deep in the sediment bed, below the depth of core penetration. Note that arsenic concentrations at the bottom of these cores ranged from 24 to 69 mg/kg and appeared to be still demonstrating an increasing concentration trend. For comparison, the New Jersey effects range-medium for arsenic in marine/estuarine sediments is 70 mg/kg (NJDEP, 1998), implying that this buried arsenic may have a significant impact on the ecosystem if exposed. Meanwhile, cadmium, chromium, mercury, and silver also showed increasing concentrations with depth; however, concentrations appear to peak in the 1960 time horizon. Concentrations of mercury in the 1963 time horizon (for the examined sampling locations) equaled 11 ±2.8 mg/kg (N = 12), which is 16 times greater than the New Jersey

effects range-medium for mercury (NJDEP, 1998). Hence, a significant inventory of heavy metals exists at depth.

The second observation is that for each metal, the downcore profile is consistent from one sampling location to another, suggesting little spatially variability. This observation suggests that local sources of metals to the Lower Passaic River (RM 0 to 7) are limited, tidal mixing is sufficient to homogenize both metal loads and concentrations prior to deposition, or metal loads arise sufficiently far enough upriver that their levels in suspended solids are well mixed prior to deposition in the Lower Passaic River (refer to Section 4.4.2 for further discussion).

The third observation is that, except for TSI locations 248 and 251, detectable metal concentrations at the bottom of each core exceed the New Jersey background concentrations for soils in the cores examined. Interestingly, the metal concentrations at the bottom of the sediment core at TSI locations 248 and 251 are approximately equal to or less than background concentrations. Moreover, the metals at these two sampling locations appear to reach peak concentration in the 1963 time horizon before the concentrations decline to background. These two lines of evidence suggest that the sediment cores collected at TSI locations 248 and 251 contain a discontinuity just below the 1963 horizon. It is anticipated that the discontinuity exists at a depth of 6-8 feet at TSI location 248 and approximately 6 feet in TSI location 251, possibly resulting from the removal of sediments that contained peak metal concentrations as observed in the other 12 dated cores. The observed metal concentrations located below the discontinuity likely represent contaminated sediments that were deposited prior to the peak metal loading, perhaps disturbed by the process that caused the discontinuity. A similar observation was made for Total PAH for TSI location 248. In this instance, the core suggests a decline in Total PAH earlier (*i.e.*, deeper) than that observed in any of the other dated cores.

4.3.7   CONTAMINANT CHRONOLOGY SUMMARY

The following conclusions and observations summarize the contaminant chronology section.

- Consistent with the observations by Bopp *et al.* (1991a) and Chaky (2003) for Newark Bay, dated sediment cores for the Lower Passaic River (RM 1 to 7) show that the major releases of 2,3,7,8-TCDD begin in the 1950s and peak in the early 1960s.
- The diagnostic ratio of 2,3,7,8-TCDD/Total TCDD of 0.7 to 0.8 can be used to trace Lower Passaic River PCDD throughout the Newark Bay complex and over the last 60 years. Based on dated sediments cores, this diagnostic ratio is observed throughout the sediments of the Lower Passaic River as far back as the 1950s. The ratio of 2,3,7,8-TCDD/Total TCDD prior to 1950 is characteristic of sewage and atmospheric fallout (less than 0.05).
- Dated sediment cores reveal that Total DDT discharges to the Lower Passaic River begin in the 1930s and peaking in the late 1940s or early 1950s, which is consistent with the observations of Bopp *et al.* (1991a). Results consistently show measurable Total DDT concentrations occurring deeper in the sediment core than measurable

2,3,7,8-TCDD concentrations, suggesting the possible application of DDT as a measure of the vertical extent of 2,3,7,8-TCDD contamination. However, there may be some limitations to the usefulness of Total DDT in this regard due to measurement sensitivity.

- Major contamination of the Lower Passaic River likely occurred in the 1930s or earlier. Elevated concentrations of arsenic (approximately 60 mg/kg), chromium (approximately 800 mg/kg), copper (approximately 700 mg/kg), lead (approximately 700 mg/kg), Total PAH (approximately 100 mg/kg), and benzo[a]pyrene (approximately 14 mg/kg) occur at depth in dated sediment cores, usually reaching a maximum at core bottoms. This evidence indicates that the vertical extent of these contaminants is undefined and that major inventories of these contaminants most likely lie below the documented depth of 2,3,7,8-TCDD contamination.

- Dated sediment cores were also unable to establish the depth of contamination for mercury and cadmium although peak concentrations (approximately 15 and 25 mg/kg, respectively) appear to occur in the 1960s, concurrent with the 2,3,7,8-TCDD maximum.

- Total PCB is found throughout the Lower Passaic River with peak values (4 to 18 mg/kg) occurring at a depth corresponding to the 1960s. Aroclor 1248 is the most commonly reported PCB mixture, typically comprising 60 percent or more of the Total PCB burden.

- An examination of Total DDT to 2,3,7,8-TCDD concentrations downcore indicted that ratio analysis was unlikely to be productive and was not pursued.

4.4   SURFACE SEDIMENT CONCENTRATION

To supplement the temporal trends displayed in the downcore profiles, surface sediment concentration scatter plots were developed to investigate spatial trends. These scatter plots were generated for metals, Total PAH, Total PCB, 2,3,7,8-TCDD, and total petroleum hydrocarbon (TPH; Figure 4-14). The 1995 surface concentrations (blue squares) represent analyte concentrations reported in core tops (0-0.5 foot) from the 1995 TSI dataset while the 1963 concentrations (red diamonds) represent interpolated analyte concentrations from the 14 dated cores (Table 2-4) that correspond to the 1963 time horizon. Interpolated 1963 concentrations could only be calculated at sampling locations where a complete radiological history was available for dating purposes (refer to the downcore profiles presented in Figure 4-1 through Figure 4-13). Note that the downcore profiles for TPH were not presented in Section 4.3[15], but they were used in Section 4.4 to interpolated 1963 concentrations.

4.4.1 TRENDS IN SURFACE CONCENTRATIONS

At first glance, the 1995 dataset appeared to exhibit little trend with river mile in view of the variability for each analyte. However, on closer inspection, some trends were apparent in the datasets. To test the hypothesis that subtle trends exist, a linear regression was first performed on the 1995 surface concentrations; however, these tests yielded poor

---

[15] TPH is not a conservative contaminant and is connected to multiple local sources. As a result, TPH is not easily characterized in a source and transport model. Temporal trends in TPH concentrations (*i.e.*, downcore profiles) are not discussed in Section 4.3; however, they were constructed (data not shown) to estimate TPH concentrations in the 1963 time horizon.

regression coefficients typically less than 0.1. The Mann-Kendall test was then performed on the data to identify whether a significant trend was present within each analyte dataset for the 1995 concentrations and the 1963 interpolated concentrations. A trend identified by this test would indicate one of the following conditions:

- Concentrations decreasing downriver suggest a likely source at the upriver end of the Lower Passaic River. In general, enhanced solubility in seawater, or tidal mixing with less contaminated solids from downriver, causes the observed downriver decrease in concentration.
- Concentrations increasing downriver suggest a likely source at the upriver end of the Lower Passaic River compounded by a second source downriver, causing the observed increase in concentration.
- No concentration trend suggests that solids load in the Lower Passaic River is well mixed prior to deposition. No evidence exists for more than one source.

Mann-Kendall results are summarized in Table 4-1; a complete list of statistical results is provided in Appendix B.

Table 4-1: Summary of Mann Kendall Results for 1963 Interpolated Concentrations and 1995 Concentrations

Analyte	1963 Trend Downriver [a, b, c]	1995 Trend Downriver [a, b, c]
Arsenic	**Increasing**	**Increasing**
Barium	No trend	No trend
Cadmium	No trend	No trend
Chromium	No trend	**Increasing**
Copper	No trend	No trend
Lead	No trend	**Decreasing**
Mercury	**Increasing**	**Increasing**
Nickel	No trend	No trend
Silver	No trend	No trend
Total PAH	No trend	**Decreasing**
Total Petroleum Hydrocarbon	No trend	No trend
2,3,7,8-TCDD	No trend	No trend
Total PCB	No trend	No trend

a: Trends are denoted as the change in concentration from upriver to downriver
b: Mann Kendall and confidence test performed according to *Guidance for Data Quality Assessment* (USEPA, 1998)
c: Refer to Appendix B for more details

For the 1995 dataset, most of the contaminants examined have no trend, yielding no evidence to suggest multiple sources. The concentrations of three metals (arsenic, chromium, and mercury) statistically increased in the downriver direction, suggesting the possibility of two sources, one at each end of the Lower Passaic River. Meanwhile, lead and total PAH had a statistically decreasing trend downriver, suggesting that their primary source exists upriver of RM 7. However, while trends were identified in these datasets, low regression coefficients and high variability only weakly support the presence of a second source with typical concentration changes of 50 percent or less. For most contaminants, tidal mixing is sufficient to homogenize the impacts of local loads, resulting in no significant gradients in the Lower Passaic River. As discussed below,

similar conditions existed in 1963, and in fact, evidence exists for an upriver source beyond the Dundee Dam for several of the contaminants (refer to Section 4.4.2, Section 4.5.1, and Section 4.5.2).

4.4.2   COMPARISON OF 1963 AND 1995 CONCENTRATIONS

Only two significant increasing trends were identified in the 1963 dataset, specifically for arsenic and mercury. Like the 1995 results, most contaminants exhibited no trend. While similar conditions existed in the 1963 and 1995 datasets, additional statistical work was necessary to conclude (1) whether the 1963 dataset is significantly different from the 1995 dataset and (2) whether the 14 locations with dated sediment cores can be considered representative of surface sediment concentrations for the Lower Passaic River (RM 0.9 to 7.0). Answers to these questions will allow the extrapolation of apparent conditions within the 14 cores to be considered representative of surface sediment conditions at the time of deposition. To test these hypotheses, the Student's T-test was performed (alpha value of 0.05). In each test, if the Student's T test fails, then the two sets of data are statistically different. Each of the tests is summarized below:

- The 1963 interpolated data (sample size 14) to the available 1995 surface concentrations dataset (sample size 95).
- The surface concentrations from the datable cores (a sub-set of the 1995 data, sample size 14) to the available 1995 surface concentration dataset (sample size 95). If the T-test fails, then the surface concentrations measured at these 14 locations are not representative of surface concentrations in the Lower Passaic River (RM 0 to 7).
- The 1963 interpolated data (sample size 14) to the sub-set of 1995 data (sample size 14) discussed above.

A summary of results is presented in Table 4-2; a complete list of statistical results is provided in Appendix B.

Table 4-2: Summary of Student's T-test Results

Analyte	Is the 1963 data different from the available 1995 dataset?	Is the 1995 sub-set different from the available 1995 dataset?	Is the 1963 data different from the 1995 Sub-set?
Arsenic	Yes	Yes	Yes
Barium	Yes	No	Yes
Cadmium	Yes	No	Yes
Chromium	Yes	Yes	Yes
Copper	Yes	No	Yes
Lead	Yes	No	Yes
Mercury	Yes	Yes	Yes
Nickel	Yes	Yes	Yes
Silver	Yes	No	Yes
Total PAH	No	No	Yes
Total Petroleum Hydrocarbon	Yes	No	Yes
2,3,7,8-TCDD [a]	Yes	Yes	Yes
Total PCB	Yes	No	Yes

a: Statistics on 2,3,7,8-TCDD represents a sample size of 13 (one outlier excluded)

The results of the first Student's T-test suggest that the interpolated 1963 dataset is statistically different than the available 1995 dataset, except for Total PAH[16]. This outcome is expected since peak loadings of contamination to the Lower Passaic River generally occurred more than 30 years prior to 1995. Thus, surface sediments are anticipated to be less contaminated than deeper sediments, despite the reworking of sediments.

The second Student's T-test examined whether the 1995 surface concentrations at the select 14 sampling locations (plotted as downcore profiles in Section 4.3) can represent surface concentrations across the Lower Passaic River in 1995. The results of the T-test varied with contaminant. A possible explanation for this outcome is that the 14 sampling locations were selected because they possessed a complete geochronology; hence, they are biased to depositional environments. Meanwhile, the available 1995 dataset includes surface concentrations measured from depositional and erosional environments. As a result, surface sediments (0-0.5 foot) will include a range of time horizons with an erosional environment having older, more contaminated sediment at the sediment surface and depositional environments having more recent, less contaminated sediment at the sediment surface. A comparison of the average surface concentration showed that indeed the average concentration in the available 1995 data was greater than the average concentration in the 14 subset of samples, suggesting that surface sediment (0-0.5 foot) from the available 1995 dataset included older, more contaminated sediment. Therefore, the expected T-test result is "Yes" the datasets are different; the observed "No" responses in Table 4-2 indicate that contaminant concentrations have not changed over time for certain analytes.

While the results of the second Student's T-test were inconclusive, it is likely that the 1963 interpolated data from the 14 select locations does not represent surface concentrations across the Lower Passaic River in the year 1963. However, it is likely that these 14 locations do represent 1963 concentrations in depositional environments. When comparing depositional environments, analyte concentrations in 1963 differed from corresponding concentrations in 1995 for all examined sampling locations as noted by the final Student's T-test.

Other studies were then referenced to evaluate further the 1963 contamination that existed in depositional environments of the Lower Passaic River. These studies include:

- Bopp *et al.* (2006) which estimated metal concentrations (cadmium, copper, lead, and mercury) in 1963 and 1985-1986 above the Dundee Dam as well as in Newark Bay.
- Bopp *et al.* (1991a) which estimated 2,3,7,8-TCDD concentrations in 1963 and 1985-1986 above the Dundee Dam, in the Lower Passaic River, and in Newark Bay.

---

[16] While Total PAH failed the Student's T-test, it should be noted that the uncertainty on the T-test value was large, 37 percent (refer to Appendix B for details).

- Bopp *et al* (1991b) which estimated Total PCB[17] and Total DDT[18] concentrations in 1963 and 1985-1986 above the Dundee Dam, in the Lower Passaic River, and in Newark Bay.

Figure 4-15 plots the 1963 interpolated data (same data as Figure 4-14) for select chemicals along with the literature 1963 concentrations. A noticeable feature is that the lead, mercury, and Total PCB concentrations measured above the Dundee Dam were approximately equal to (within one standard deviation), or greater than, the average concentration observed in the Lower Passaic River (RM 1 to 7). This comparison strongly suggests that the source of contamination for these contaminants in 1963 is likely upriver of the dam. In contrast, cadmium, copper, and Total DDT concentrations above the dam are *less* than the average concentration observed in the Lower Passaic River, suggesting that an additional contaminant source is located below the dam. For cadmium, copper, and Total DDT, the contribution from the upriver source varies. For example, cadmium concentrations increase by 50 percent below the dam, suggesting that the larger source of cadmium is upriver of the dam. Copper concentrations increase by a factor of 2, suggesting that the upriver and downriver sources are of comparable magnitude. Finally, Total DDT concentrations increase by a factor of 5, indicating that the major source is clearly in the Lower Passaic River and that the source upriver of the dam is only a minor contributor.[19] A notable concentration differences is observed for 2,3,7,8-TCDD with a concentration measured above the Dundee Dam that is two orders of magnitude *less* than the 2,3,7,8-TCDD concentration measured in Lower Passaic River (RM 1 to 7). Hence, the source of 2,3,7,8-TCDD contamination in the Lower Passaic River in 1963 is likely located below the dam and no significant source exists upriver. Table 4-3 summarizes these 1963 concentrations.

Table 4-3: Summary of 1963 Concentrations with Literature Values

Analyte (units)	Lower Passaic River 1963 Concentration [a]	Above Dundee Dam 1963 Concentration [b]
Cadmium (mg/kg)	19 ±5	12
Copper (mg/kg)	500 ±120	250
Lead (mg/kg)	670 ±100	570
Mercury (mg/kg)	11 ±2.8	13
Total PCB (mg/kg)	6.8 ±3.8	15
2,3,7,8-TCDD (µg/kg) [c]	11 ±8.5	<0.06 [d]
Total DDT (µg/kg)	720 ±550	140 [e]

a: Average and standard deviation (± 1 sigma) for RM 2 to 7 (Tierra Solutions, Inc., 1995)
b: Reported literature values (Bopp *et al*., 2006; Bopp *et al*., 1991a; Bopp *et al*., 1991b)

---

[17] Total PCB in the Bopp *et al*. (1991b) study was defined as the sum of Aroclor 1242 and Aroclor 1254 whereas Total PCB in this geochemical evaluation (refer to Section 2.2.1) is defined as the sum of Aroclor 1248, Aroclor 1254, and Aroclor 1260.
[18] Total DDT in the Bopp *et al*. (1991b) study was defined as the sum of 4,4′-DDT and 4,4′-DDD whereas Total DDT in this geochemical evaluation (refer to Section 2.2.1) is defined as the sum of 4,4′-DDT, 4,4′-DDD, and 4,4′-DDE.
[19] Note that the Bopp *et al*. (1991b) reference did not provide a measure of 4,4′-DDE. Addition of 4,4′-DDE to the Total DDT estimate would be expected to raise the concentration and decrease the difference between the upriver and downriver values. It is viewed as unlikely, however, that this missing component would change the conclusion that the majority of Total DDT originated in the Lower Passaic River around 1963.

Table 4-3 (continued)
c: Average 2,3,7,8-TCDD concentration represents a sample size of 13 (one outlier excluded)
d: The ratio of 2,3,7,8-TCDD/Total TCDD was not available for this datum.
e: Total DDT as defined by Bopp *et al.*, 1991b is the sum of 4,4′-DDT and 4,4′-DDD

4.4.3 POTENTIAL EROSION FROM RIVER MILE 3 TO 4.5

One last series of observations can be made concerning the coincidence of surface sediment contamination and locally elevated erosion rates between RM 3 and 4.5. In particular, Figure 4-14 consistently shows a higher frequency of high outlier values in this region. These surface concentrations are frequently similar to the concentrations typical of 1963 conditions as shown by the commingling of the higher 1995 values with the 1963 values plotted in Figure 4-14. This observation suggests a higher occurrence of older contaminated sediments at the surface in this region. The fact that essentially all analytes examined yield outlier values in this river region is further evidence for a unique condition in this area (RM 3 to 4.5). A local source of contamination would be expected to generate elevated concentrations for one or two associated contaminants. The fact that outlier values are observed for nearly all analytes, even those with known sources upriver, suggests the re-exposure of older sediments.

An examination of the erosional characteristics shows that this region is characterized by locally large areas of deposition and erosion. Visual inspection of Figure 3-3 suggests that the extent of erosional areas may be greater than that of other areas in the Lower Passaic River. Together, these observations suggest that this region (RM 3 to 4.5) may be an important continuing source of older contaminated sediments to the Lower Passaic River. Currently, the evidence for the importance of this area remains somewhat anecdotal since the observation of the outlier coincidence is inherently based on a limited subset of the data. However, the outliers typically come from the same samples and many of these samples are found in, or near areas, determined through the bathymetric evaluations to be erosional. Some of this coincidence may simply be due to sampling density although notably the next river mile downriver was similarly sampled but does not exhibit the same degree of outliers. Given its proximity to the historical discharge sites on the Lower Passaic River, and the large documented inventory in RM 3 to 4.5 (see Section 4.4.3), this area warrants further investigation and analysis.

4.4.4 SURFACE SEDIMENT CONCENTRATION SUMMARY

The following conclusions and observations summarize the surface sediment section.

- Dated sediment cores from the Upper and Lower Passaic River were used to differentiate the source regions for several major contaminants. These cores suggest that the major historical loads of cadmium, lead, mercury, and Total PCB primarily originated in the Upper Passaic River above the Dundee dam. A substantial load of copper also originated above the Dundee Dam, but an additional load was also present downriver. Smaller contaminant sources, particularly mercury, may also have existed in the Lower Passaic River (RM 0.9 to 7.0).
- Dated sediment cores from the Upper and Lower Passaic River further indicate that relatively little of the Total DDT and much less than 1 percent of the 2,3,7,8-TCDD

contamination in the Lower Passaic River originated above the Dundee Dam historically.

- An examination of the 1995 surface sediments in the Lower Passaic River suggests that at least two sources for arsenic, chromium, and mercury are present (one at or below RM 1 and one at or above RM 7). Dated sediment cores show a similar condition for arsenic and mercury in 1963. The likely upriver mercury source is the one originating upriver of the Dundee Dam.

- Surface sediment data in the RM 3.5 to 4 region had a relatively high frequency of outlier values, occurring across all contaminants, suggesting that this region may have a number of locations undergoing erosion and exposing older, more contaminated sediments. The consistent occurrence of these outliers across all contaminant types tends to rule out the possibility of an ongoing local source since it would need to include all of the major contaminants. This conclusion requires further evaluation.

- Ratio analysis of metal contamination in the Lower Passaic River (RM 0.9 to 7.0) showed little variation in the metals pattern. Analysis of surface metal concentrations also showed relatively little trend with river mile. This evidence demonstrates the homogeneity of surficial sediments in the Lower Passaic River and suggests that tidal mixing is able to homogenize local metals loads over long distances, prior to the deposition of the contaminants in the river bottom.

- Organic contaminant concentrations in the Lower Passaic River exhibited a greater variance than the metal concentrations. Nonetheless, few trends were apparent with river mile (only Total PAH exhibited a trend), again suggesting extensive tidal mixing of suspended matter prior to settling and storage as river sediments.

4.5   SOURCE ANALYSIS

While the downcore profiles (Section 4.3) and scatter plots (Section 4.4) provide information on spatial and temporal trends, further geochemical evaluations were necessary to characterize contaminant sources. Evaluations were completed to investigate the nature and location of sources for metals, Total DDT, Total PCB, 2,3,7,8-TCDD, and Total PAH.

4.5.1   METALS SOURCE ANALYSIS

Radar plots were constructed to characterize potential sources of metals in the Lower Passaic River. (Mass fractions were plotted to avoid confounding by concentration trends.) These radar plots focused on 9 metals, including arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, and silver. Figure 4-16 presents 7 radar plots, one plot per river mile from RM 1 to 7, and then a final radar plot, which presents one representative sampling location per river mile. The result of this evaluation is striking; each of the one-mile segments in the Lower Passaic River (RM 1 to 7) possess essentially the same mass fraction ratios of metals. To yield such consistent ratios, the sources of much of the metal contamination are likely to be upriver of RM 7. Moreover, these metals sources must be far enough upriver so that by the time contaminated sediments are transported to RM 7 they are well mixed, yielding consistent mass fraction patterns. Note that the sample results for RM 5 suggest a secondary source of metals, resulting in relatively minor scatter in the data. The results of the radar plots relate directly back to (1) the downcore profiles (Section 4.3.6), which showed consistent metal profiles among

the various sampling locations, suggesting a limited number of local sources, and (2) the 1963 interpolated data (Section 4.4.2), which showed that the concentration of metals above the Dundee Dam in 1963 were comparable for several metals to the average metal concentrations measured in the Lower Passaic River in 1963.

Similar to the comparison of metal concentrations in 1963 (refer to Section 4.4.2 and Table 4-3), Bopp *et al.* (2006) also provides dated metals concentrations for four metals (lead, copper, cadmium, and mercury) from above Dundee Dam in 1985-1986 (Figure 4-15). Table 4-4 compares the 1985-1986 concentrations with the 1995 surface sediment concentrations to evaluate the relative comparability of the data. A comparison between the 1995 and 1985 data is valid here based on the observation that metal concentrations in the sediments were not changing as rapidly during this period as in previous periods, as documented by the down core profiles. Additionally, the 1995 samples are not constrained by radiological dating, and thus, they may represent a longer time period than the 1985 samples, making the values more directly comparable.

Table 4-4: Summary of 1995 Inorganic Concentrations with Literature Values

Analyte (units)	Lower Passaic River 1995 Concentration [a, b]	Dundee Dam 1985-1986 Concentration [c]
Cadmium (mg/kg)	5.1 ±3.1 (N = 95)	4.2
Copper (mg/kg)	230 ±250 (N = 95)	120
Lead (mg/kg)	330 ±150 (N =90)	307
Mercury (mg/kg)	3.3 ±1.9 (N = 92)	1.8

a: Average, standard deviation (± 1 sigma), and sample size (N) for RM 1 to 7 (Tierra Solutions, Inc., 1995); nondetected values are incorporated into the average as half the reported detection limit.
b: 1995 surface concentrations are defined as 0-0.5 foot. As noted in Section 4.4.1, samples include depositional and non-depositional environments; hence, the temporal component of these samples is less constrained than the literature values corresponding to 1985-1986.
c: Reported literature values (Bopp *et al.*, 2006)

In general, the metal concentrations in 1985-1986 are comparable to the corresponding metal concentrations measured in 1995 (within one standard deviation). However, both the copper and mercury concentrations above the dam were on the low end of the average Passaic-concentration, suggesting a potential source of copper and mercury below the dam. To investigate whether the metals signature was similar in 1985-1986 and 1995, ratios of specific metals were evaluated and compared. If the ratios of metals above and below the dam are similar, then only the magnitude of the metals loadings have changed from 1985-1986 to 1995. If the ratios are different, then another source was possibly impacting concentrations from 1985-1986 to 1995.

To accomplish this comparison, radar plots were prepared following the method described above (Section 2.3.2) for cadmium, copper, lead, and mercury for samples collected above Dundee Dam and from selected locations within the Lower Passaic River (Figure 4-17). The similar shape of radar plots indicates that the mass fraction of the four metals is similar above and below the dam. However, a more detailed analysis of metal ratios above Dundee Dam compared with the same ratios' range and means in the Lower Passaic River revealed that ratios involving copper are different above the dam than below the dam (Figure 4-18). These comparisons, albeit based on only two samples [one

sample from 1963 (Table 4-3) and one sample from 1985-1986 (Table 4-4)], suggest that much of the lead, cadmium, and mercury in the Lower Passaic River originates above the Dundee Dam. The range of ratios observed upriver is similar to those observed downriver. However, a significant source of copper on the Lower Passaic River is suggested by the poor agreement of the copper based ratios. Based on the change in surface sediment concentrations, it is likely that a Passaic-copper source accounts for roughly half of the copper inventory below Dundee Dam. Because of the limited data above Dundee Dam, and the wide variation of 1995 surface concentrations in the Lower Passaic River (refer to Section 4.4.2), potential additional, but relatively smaller, sources of lead, cadmium, and mercury on the Lower Passaic River cannot be completely discounted by these analyses.

4.5.2   TOTAL DDT, TOTAL PCB, AND 2,3,7,8-TCDD SOURCE ANALYSIS

Similar to the metal analysis, the concentration of Total DDT, Total PCB, and 2,3,7,8-TCDD were examined above and below the Dundee Dam using the 1995 dataset and literature values representing the 1985-1986 time period (Figure 4-15). For all three contaminants, the concentrations reported above the dam are *less* than the average Passaic River-concentration (but they are within one standard deviation about the mean for the 1995 dataset). These data provide additional information on contaminant load to the Lower Passaic River. For example, Total PCB and Total DDT concentrations increase by a factor of 3 to 4 below the dam, suggesting that the contaminant load below the dam is approximately 2 to 3 time greater than the contaminant load above the dam.

The observed increase for Total DDT is consistent with the observations for the 1963 period, as discussed previously (see Table 4-3). Note that no data exists to estimate historical loads of Total DDT prior to 1963 despite the evidence for nearly 20 years of Total DDT loading prior to 1963 to the Lower Passaic River, as documented in Lower Passaic River cores.

The relationship for Total PCB appears to have changed over time. In 1963, it appeared that the Upper Passaic River was responsible for most of the Total PCB burden of the Lower Passaic River. In the 1985-1995 period, however, the importance of this flux has diminished such that downriver concentrations increase by roughly three fold, suggesting an ongoing Lower Passaic River source of Total PCB, which may be as much as two times greater than the Upper Passaic River source. Meanwhile, the 2,3,7,8-TCDD concentration for the 1985-1995 time period increases by a factor of 40, suggesting that the contaminant load below the dam is approximately 40 times the contaminant load above the dam. This observation is consistent with the 1963 conditions as well, identifying the vastly greater 2,3,7,8-TCDD source of the Lower Passaic River. Results are summarized in Table 4-5.

Table 4-5: Summary of 1995 Organic Concentration with Literature Values

Analyte (units)	Lower Passaic River 1995 Concentration [a, b]	Dundee Dam 1985-1986 Concentration [c]
Total PCB (µg/kg)	1,300 ±1,800 (N = 90)	480
Total DDT (µg/kg)	300 ±740 (N = 95)	68[d]
2,3,7,8-TCDD (µg/kg)	0.81 ±2.0 (N = 95)	0.02

a: Average, standard deviation (± 1 sigma), and sample size (N) for RM 0 to 7 (Tierra Solutions, Inc., 1995); nondetected values are incorporated into the average as half the reported detection limit.
b: 1995 surface concentrations are defined as 0-0.5 foot. As noted in Section 4.4.1, samples include depositional and non-depositional environments; hence, the temporal component is less constrained than the literature values corresponding to 1985-1986.
c: Reported literature values (Bopp *et al.*, 2006; Bopp *et al.*, 1991a, Bopp *et al.*, 1991b)
d: Note that the Bopp *et al.* (1991b) reference did not provide a measure of 4,4′-DDE. Addition of 4,4′DDE to the Total DDT estimate would be expected to raise the concentration and decrease the difference between the upriver and downriver values. It is viewed as unlikely, however, that this missing component would change the conclusion that the majority of Total DDT continues to originate in the Lower Passaic River.

To further investigate and characterize the source of Total DDT below the Dundee Dam, diagnostic ratios were calculated using the DDT isomers. Historically, DDT was widely used to control insects on agricultural crops and insects that carried diseases like malaria and typhus. The use of DDT in developed countries, such as the U.S., was halted when studies showed DDT accumulation in the environment and biomagnification in organisms at the tops of food chains (Boul, 1994). Technical grade DDT (the grade that was generally used as an insecticide) was composed of up to fourteen chemical compounds with the active ingredient 4,4′-DDT accounting for 65–80 percent of the mixture and the nearly inactive ingredient 2,4′-DDT accounting for 15–21 percent of the mixture. Other components included up to 4 percent of 4,4′-DDD and up to 1.5 percent of 1-(p-chlorophenyl)-2,2,2-trichloroethanol (Metcalf, 1995).

The major releases of Total DDT to the Lower Passaic River are alleged to be the result of DDT manufacture and not agricultural application. If different ratios were observed in Lower Passaic River sediment relative to published literature values for agriculturally-applied DDT, then sources of Total DDT could be potentially fingerprinted. For agriculturally-applied DDT, the ratio of 2,4'-DDT to the sum of all isomers usually averages around 0.25 for agriculturally applied DDT (MacGregor, 1974). A review of available data for the Lower Passaic River indicated that only surface sediment samples collected in 1993 were analyzed for both the 2,4'-isomers and the 4,4'-isomers. The distribution of the estimated ratio for the 1993 surface samples is given in Figure 4-19. This ratio averaged around 0.20, which was consistent with the commercial composition of DDT that is applied agriculturally. Note that because subsurface data on the various DDT forms were not available, a determination of historical patterns to distinguish other possible historical sources could not be completed.

4.5.3 PAH SOURCE ANALYSIS

Both natural and anthropogenic sources release PAH compounds into the environment. The natural source is the short-term diagenetic products derived from biogenic precursors (*e.g.*, sedimentary early diagenesis processes). Meanwhile, anthropogenic sources

include both "petrogenic" sources derived from slow maturation of organic matter under geothermal gradient conditions and "pyrogenic" sources derived from incomplete combustion of recent (*e.g.*, biomass burning) and fossil (*e.g.*, coal) organic matter (Baumard *et al.*, 1998; Soclo *et al.*, 2000). In a highly urbanized area, like the New York/New Jersey Harbor, the PAH flux from natural sources is considered a minor component of the total flux when compared to the inputs by anthropogenic sources (Canton and Grimalt, 1992; Gearing *et al.*, 1991). Moreover, studies suggest that the Total PAH flux in urban areas is constant or has increased over the past decade (Van Metre *et al.*, 2000; Lima *et al.*, 2003), implying that the fluxes from anthropogenic sources are also constant or have increased recently.

The development of PAH indicators is necessary to further evaluate the impact of anthropogenic PAH sources on urban areas and to evaluate the contributions from petrogenic and pyrogenic sources. Examples of potential PAH indicators include PAH molecular distributions or PAH ratios. Yan *et al.* (2004) recently investigated the PAH distribution in sediments from the New York/New Jersey Harbor and identified four molecular ratios that were potential indicators of PAH sources. These ratios include:

- Fluoranthene to the sum of fluoranthene plus pyrene [FL/(FL+PY)]
- The proportion of 4-ring, 5-ring, and 6-ring PAH compounds to Total PAH (Ring456/Total PAH).
- Parental PAH compounds to parental PAH compounds plus respective alkylated homologues.[20]
- Parental PAH compounds to parental PAH compounds plus respective alkylated homologues, specifically for fluoranthene and pyrene.

Using these ratios, Yan *et al*. (2004) suggested that pyrogenic PAH sources were dominant in the New York/New Jersey Harbor with petrogenic PAH sources contributing to the total flux in the Kill van Kull.

Pyrogenic, or combustion-related, PAH sources can originate from weathered/degraded coal tars residues, which are by-product of manufactured gas plants, or from urban background sources. Geochemical tools are necessary to distinguish between these two sources because of the compositional similarity between coal tar residues and background urban combustion in sediments. Recently, Costa and Sauer (2005) described a simple approach to distinguish between HMW PAH that was associated with coal tar sources and combustion-related PAH that was associated with urban background combustion. Their approach used unsubstituted PAH ratios in double-ratio scatter plots to determine source signatures that were quantitatively defined by point clusters. The double-ratio plots included:

- Benz[a]anthracene/chrysene versus fluoranthene/pyrene
- Benz[a]anthracene/benzo[a]pyrene versus fluoranthene/pyrene

---

[20] The 1995 TSI dataset does not include substituted PAH compounds; hence the ratios that include alkylated homologues could not be calculated.

- Chrysene/benzo[a]pyrene versus fluoranthene/pyrene.

By applying these ratios to the available PAH dataset, the PAH source on the Lower Passaic River was investigated. As discussed in Section 4.4.1, Total PAH concentrations in surficial sediment in the Lower Passaic River (RM 1 to 7) were rather homogenous with concentrations primarily ranging from 10 to 100 mg/kg (Figure 4-14). Moreover, Total PAH concentrations in subsurface sediments were of similar magnitude to surficial concentrations until the 1940 time horizon when concentrations increased (Figure 4-2; Section 4.3.2). Because of these temporal trends, a weak relationship exists between Total PAH concentrations and core depth as depicted by the weighted curve in Figure 4-20.

To decipher PAH sources, Total PAH concentrations were manipulated to construct ratios from the individual PAH constituents. Ratios were then evaluated in a double-ratio scatter plot, which compared FL/(FL+PY) with Ring456/Total PAH (Figure 4-21). The first observation in this plot is that 94 percent of the 495 sediment samples examined had a FL/(FL+PY) ratio greater than 0.4, suggesting a predominantly combustion-derived source. The second observation is that a large percentage of the PAH constituents were considered HMW PAH (contained more than 4 rings in their structure), a signature of a pyrogenic source. For example, only 10 of the 495 samples had a ratio of Ring456/Total PAH less than 0.5, implying that for these 10 samples only, the low molecular weight PAH composition was greater than the HMW PAH composition. This analysis supports the observation in Section 4.3.2 that HMW PAH concentration accounted for 81 percent of the Total PAH concentration. Lastly, unlike the FL/(FL+PY) ratio, which was relatively constrained, the Ring456/Total PAH ratio varied from 0.3 to 1, suggesting the possibility of multiple combustion related sources.

Other PAH ratios were then calculated and compared to identify a PAH source in the Lower Passaic River (Figure 4-22). In this evaluation, PAH ratios are compared to the ratio of FL/PY, which is mathematically related to the ratio of FL/(FL+PY) that was presented in Figure 4-21. A value of 0.67 for the ratio of FL/PY is equivalent to a FL/(FL+PY) value of 0.4, and both values represent a combustion-related signature. The double-ratio scatter plots in Figure 4-22 show both the Lower Passaic River sediment data and end member sources characterized by Costa and Sauer (2005), including coal tar (a by-product of manufacturing gas plants), creosote, and urban background. For the three PAH ratios examined, the data suggest that two sources exist: a coal-tar related source and an urban background source. Moreover, the majority of the sediment data represent a mixture of these two sources. (Creosote does not appear to be an important PAH source in the river.) Furthermore, a slight gradient exists in Total PAH concentration as the FL/PY ratio moves to a coal tar source signature (Figure 4-23). This analysis suggests that the signature of the combustion related PAHs in the Lower Passaic River sediment is dominated by coal tar, a typical waste material at manufacturing gas plants , which have historically existed in the Passaic watershed.

Three principal components, which accounted for a combined 60 percent of the total data variability, were extracted from the principal component analysis of PAH data (Figure 4-

24). The first principal components (PC1) only explained 27 percent of the variance in the data and was influenced by the separation of the 4-ring and 5-ring PAH compounds from the other compounds. This separation highlights the petrogenic and combustion sources that are present in the system. While combustion sources dominate the Total PAH concentration, petrogenic sources were evident in the Lower Passaic River sediment with TPH concentrations in surface sediment ranging from 100 to 1,000 mg/kg (Figure 4-14). However, since TPH is not a PAH compound, the Total PAH concentration is not necessarily correlated to TPH.

Note that the variability explained by PC1 in this current analysis is lower than the PC1 reported in the Preliminary Geochemical Evaluation, which was conducted on surface sediments only. Nevertheless, the PC1 patterns in both evaluations are consistent. The second and third principal components accounted for 17 percent and 14 percent of the variability, respectively.

4.5.4 SOURCE ANALYSIS SUMMARY

The following conclusions and observations summarize the source analysis section.

- The examination of surface sediment and dated sediment cores located above and below Dundee Dam indicates that concentrations of examined contaminants have declined everywhere to some degree relative to 1963 conditions.
- An examination of metal ratios in dated sediment cores and surface sediment samples further supports the origin of Lower Passaic River cadmium, lead, and mercury contamination above the Dundee Dam.
- In 1995, metals concentrations above the Dundee Dam for cadmium, lead, and mercury are comparable in magnitude to their concentrations downriver, further supporting the conclusion that the Upper Passaic River continues to be responsible for much of the cadmium, lead, and mercury contamination in the Lower Passaic River.
- In 1963, the Total PCB source upriver of the Dundee Dam accounted for the majority of the Total PCB load in the Lower Passaic River. However, evidence suggests that currently (*circa* 1995), the Upper Passaic River Total PCB source has become less important relative to Lower Passaic River Total PCB load. Nevertheless, the Upper Passaic River source may still comprise one third of the Total PCB loading in the Lower Passaic River.
- Total DDT loads from the Upper Passaic River remain relatively small as compared to the Lower Passaic River loads with the Upper Passaic River contributing perhaps one quarter of the Total DDT input.
- The Upper Passaic River remains a trivial source of 2,3,7,8-TCDD to the Lower Passaic River despite the passage of time. The Upper Passaic River is unlikely to represent more than 2 percent of the total loading to the Lower Passaic River.
- Ratio analysis of the 2,4′-DDT and 4,4′-DDT and its metabolites did not yield a diagnostic ratio for the surface sediments of the Lower Passaic River. The ratio was similar to the signature of agriculturally applied DDT. No data were available to examine deeper sediments.
- Ratio analysis of Total PAH shows that the majority of sediment contamination is derived from combustion-related processes. The ratio "fingerprint" suggests that

Total PAH originates from two sources: coal tar residue (a by-product of manufactured gas plants) and urban background combustion. Of these two sources, coal tar wastes are the dominant source, based on the prevalence of coal tar-like PAH ratios in the sediments. The same analysis essentially rules out creosote-derived contamination and suggests only minor portions of the sediment PAH contamination is derived from a petrogenic source.

- The principal component analysis shows the occurrence of occasional petroleum-based PAH contamination distributed randomly throughout the Lower Passaic River. This observation is supported by the pervasive level of TPH (100 to 1,000 mg/kg) found throughout the Lower Passaic River (RM 0.9 to 7.0).
- There is no basis available to estimate loads from the Upper Passaic River prior to 1963 and only a limited basis to estimate them post 1963. This represents a significant data gap given the evidence for the importance of the Upper Passaic River source.
- These source analyses and the previous subsections of Section 4.0 underscore the importance of investigating the contaminant chronology at the Dundee Dam, given the loads that continue to originate there.

4.6   CHEMICAL MASS BALANCE

Evaluations discussed to this point suggest that the main sources of contaminated sediments to the Lower Passaic River are located either upriver of the Dundee Dam (*e.g.*, metals, Total PAH, and Total PCB) or located along the river as local sources (*e.g.*, Total DDT and 2,3,7,8-TCDD). Three observations suggest that Newark Bay sediments are not being transported into the Lower Passaic River at any significant scale and that, for most contaminants, transport upriver from the bay is even less important:

- The intensity of the concentration gradients at the mouth of the Passaic River.
- The homogeneity of the contaminant concentrations within the Lower Passaic River (RM 1 to 7).
- The similarity of upriver sediment concentrations to those concentrations in the Lower Passaic River (RM 1 to 7).

Instead, Passaic-contaminated sediments are likely being transported into Newark Bay and impacting Newark Bay sediment quality (refer to Section 3.3 and Table 3-3).

To further evaluate the impact of Passaic-contaminated sediment in Newark Bay, chemical mass balances for 2,3,7,8-TCDD, Total TCDD, and mercury were developed beginning with the revised solids mass balance presented in Table 3-3 and surface concentration data for the Lower Passaic River, Newark Bay, the Hackensack River, and the Kills (Table 4-5). Surface concentrations equaled the average concentration recorded from 1990-2000. Note that since several studies were considered in this analysis, a surface sediment was defined as samples having depth top equal to zero (no restrictions

were applied to the depth of the sample bottom)[21]. The mean concentrations of 2,3,7,8-TCDD, Total TCDD, and mercury are provided in Table 4-6 along with a count of the number of samples included in the average. In general, the means were calculated on the basis of mainstem samples, avoiding samples located in inlets, where possible.

Table 4-6: Surface Concentrations Used in the Mass Balances for Newark Bay

Source	2,3,7,8-TCDD Concentration (μg/kg) [a,b]	Total TCDD Concentration (μg/kg) [a,b]	Ratio of 2,3,7,8-TCDD to Total TCDD (unitless)	Mercury Concentration (mg/kg) [a,b]
Passaic River	0.54 (N = 255)	0.68 (N = 255)	0.8	3.4 (N=104)
Hackensack River	0.093 (N = 5)	0.14 (N = 5)	0.67	4.0 (N=5)
CSO/WWTP [c]	UK [d]	UK	UK	UK
Atmospheric Deposition	UK	UK	UK	UK
Kill van Kull	0.01 [e]	0.07 [e]	0.15	1.1 (N=5)
Arthur Kill	0.05	0.18	0.28	1.6 (N=4)
Newark Bay	0.076 (N = 32)	0.16 (N = 32)	0.56	2.4 (N=48)

a: Average (sample size)
b: Concentrations represent average surface sediment concentrations from 1991 to 1995, unless otherwise noted.
c: CSO = Combined sewage overflow; WWTP = Waste water treatment plant
d: UK = unknown value.
e. Concentration represents New York harbor sediments from dated sediment cores at the entry to Kill van Kull 1994-1998 (Chaky, 2003).

4.6.1   2,3,7,8-TCDD AND TOTAL TCDD MASS BALANCE

To constrain the mass balance calculations for Newark Bay, both 2,3,7,8-TCDD and Total TCDD were balanced simultaneously. Then, a separate mass balance was completed for mercury. Because the ratio of 2,3,7,8-TCDD and Total TCDD is well known throughout the Newark Bay area and their geochemistries are similar, they provide essentially conservative tracers of solids in the Newark Bay area. Fitting a mass balance to them provides a powerful constraint on the mass balance calculations since loads of both contaminants must be matched with the same set of solids inputs.

The mass balance calculation followed the framework laid out by Lowe *et al.* (2005), that is, the solids and contaminant mass removed by dredging in Newark Bay has to be replenished by external loads to the bay. Properties of suspended solids for each of the major end members (*e.g.,* the Lower Passaic River and the Kill van Kull) are estimated from contemporaneous surface sediment measurements. Similarly, concentrations for Newark Bay dredged materials were estimated from surface sediments collected from the bay. The time frame for the three mass balances is the 1990 to 1995 period. This time

---

[21] Some core segments in Newark Bay extended from 0-4 feet. However, since the mean and median concentration for 2,3,7,8-TCDD are approximately the same, then the impact of outliers due to deep core segments is considered unimportant.

period simulates when surface concentrations were not varying rapidly for most of the bay and its environs at the time, based on dated sediment core evidence. This mass balance approach has some of the same weaknesses as the original solids balance (Table 3-3; Section 3.3) since deposition in non-dredging areas is ignored with the exception of the Lower Passaic River.

Using the revised solids mass balance derived in Section 3.3 (Table 3-3), mass balances were calculated for both 2,3,7,8-TCDD and Total TCDD. As a first attempt, the 2,3,7,8-TCDD came fairly close to the target value for Newark Bay sediments but the Total TCDD concentration was too high, yielding a low ratio for the Newark Bay sediments. This scenario suggested that the solids loads needed to be adjusted to maintain the 2,3,7,8-TCDD loading but reduce the Total TCDD load. To correct the observation, an adjustment was made to the solids mass balance, increasing the solids delivered by the Lower Passaic River (with a known diagnostic 2,3,7,8-TCDD/Total TCDD ratio of 0.7 or greater) and slightly decreasing the solids loads from the Kills. In making this correction, the overall volume of solids dredged was held constant as was the proportion of the Arthur Kill to the Kill van Kull based on the analysis of Lowe *et al.*, (2005). The results indicated that to balance the two compounds simultaneously, the solids load from the Lower Passaic River was equal to 35,600 cubic yard/year or about 45 percent of the total solids estimated to enter the Lower Passaic River from above the head of tide. The new solids balance is presented in Table 4-7, along with the two previous solids loads estimates.

Table 4-7: Updated Mass Balance for Solids for Newark Bay

Source of Solids	Lowe *et al*. Mass Balance (cubic yards) [a]	Estimated Mass Balance - Solids Only (cubic yards) [a]	Estimated Mass Balance - Chemistry and Solids (cubic yards)
Passaic River	79,100	12,400	35,600
Hackensack River	6,460	6,460	6,460
Combined Sewer/Water Treatment	10,500	10,500	10,500
Atmospheric Deposition	285	285	285
Kill van Kull	205,000	260,000	241,000
Arthur Kill	41,900	53,200	49,300

a: From Table 3-3; Section 3.3

The adjustment made to the solids load from the Lower Passaic River was essential to balance 2,3,7,8-TCDD and Total TCDD simultaneously. No other source to Newark Bay had the correct characteristics (*e.g.*, high 2,3,7,8-TCDD concentrations and low Total TCDD) to complete the mass balance. Thus, the chemical mass balance provides an additional constraint on the solids mass balance. Note that the increase of the Passaic-solids load from 12,400 cubic yard/year (Table 3-3) to 35,600 cubic yard/year (Table 4-7) is considered to be within the uncertainty of the possible Lower Passaic River loads. Both the volume of solids deposited annually as well as the mass of solids delivered to the Lower Passaic River have sufficient uncertainty that the solids load requirement for this chemical mass balance is considered to be well within the likely range of conditions.

The mass balance results for 2,3,7,8-TCDD and Total TCDD are presented in Table 4-8. The annual load of 2,3,7,8-TCDD (units of gram/year) was calculated from the measured concentration of 2,3,7,8-TCDD in each waterbody multiplied by the revised solids mass balance (Table 4-7). The total mass of 2,3,7,8-TCDD entering Newark Bay is approximately 14 g/year, resulting in a calculated Newark Bay sediment concentration for 2,3,7,8-TCDD of 0.083 µg/kg (annual load divided by solids load). Since this calculated concentration approximates the measured 2,3,7,8-TCDD concentration (0.076 µg/kg; Table 4-6), no other major sources of 2,3,7,8-TCDD are present, and the chemical mass balance is considered closed. Similarly for Total TCDD, the mass balance appears closed since the estimated surface concentration match the measured concentration in Newark Bay (Table 4-6). The balance is further verified by the estimated ratio of 2,3,7,8-TCDD/Total TCDD, which also matches the measured data.

Table 4-8: 2,3,7,8-TCDD Mass Balance for Newark Bay

Source	Solids Mass Balance [a]		2,3,7,8-TCDD Concentration	2,3,7,8-TCDD Annual Load	Total TCDD Concentration	Total TCDD Annual Load	Ratio of 2,3,7,8-TCDD to Total TCDD
	cubic yard/year	Metric-ton/year	(µg/kg) [b]	(g/year)	(µg/kg) [b]	(g/year)	(unitless)
Passaic River	35,600	21,200	0.54	12	0.68	14	0.8
Hackensack River	6,460	3,870	0.093	0.36	0.14	0.54	0.67
CSO/WWTP [c]	10,500	6,300	UK [d]	UK	UK	UK	UK
Atmospheric Deposition	285	170	UK	UK	UK	UK	UK
Kill van Kull	241,000	116,000	0.01 [e]	1.16	0.07	7.7	0.15
Arthur Kill	49,300	23,700	0.05	1.19	0.18	4.2	0.28
Total	343,000	171,000		14		26	
Newark Bay Calculated			**0.083**		**0.15**		**0.53**
Newark Bay Measured			**0.076**		**0.16**		**0.56**
Total Annual Load	**343,000 cubic yard/year**			**14 g/year**		**26 g/year**	

a: Solids mass balance based on Lowe, *et al*. (2005) with several adjustments made to satisfy the chemical mass balance (Section 4.6.1). Conversion of sediment volume to sediment mass as given by Lowe, *et al* (2005).
b: Concentrations represent average surface sediment concentrations for 1991 to 1995 sediments, unless otherwise noted.
c: CSO = Combined sewage overflow; WWTP = Waste water treatment plant
d: UK = unknown value. Mass fluxes for sources within unknown values were set to zero for the chemical mass balance.
e. Concentration represents mean New York harbor sediments at the entry to Kill van Kull 1994-1998 (Chaky, 2003).

4.6.2 MERCURY MASS BALANCE

Substituting mercury surface concentrations into the updated solids mass balance (Table 4-7) did not yield a closed mass balance. Unlike the 2,3,7,8-TCDD and Total TCDD

---

mass balances, the mercury mass balance required an additional, substantive mercury source to complete the balance (Table 4-9). The total mass of mercury entering Newark Bay from known sources is 259,000 g/year. This annual load yields a calculated Newark Bay sediment concentration for mercury of 1.5 mg/kg (annual load divided by solids load). The concentration is much less than the measured mercury concentration in Newark Bay of 2.4 mg/kg (Table 4-6), which implies that another source of mercury is impacting Newark Bay. To complete the mercury mass balance, an additional source producing 150,000 g/year is required to generate a calculated Newark Bay sediment concentration of 2.4 mg/kg. Note that this calculation assumes that the additional source of mercury does not contribute any substantive solids to the system.

Table 4-9: Mercury Mass Balance for Newark Bay

Source	Solids Mass Balance [a]		Mercury Concentration	Mercury Annual Load
	Cubic yard/year	Metric-ton/year	(mg/kg) [b]	(g/year)
Passaic River	35,600	21,200	3.4	73,000
Hackensack River	6,460	3,870	4.0	16,000
CSO/WWTP [c]	10,500	6,300	UK [d]	UK
Atmospheric Deposition	285	170	UK	UK
Kill van Kull	241,000	116,000	1.1	132,000
Arthur Kill	49,300	23,700	1.6	38,000
Total	343,000	171,000		259,000
Newark Bay Calculated			**1.5**	
Missing Mercury Source				150,000
New Newark Bay Calculated			**2.4**	
Newark Bay Measured			**2.4**	
Net Annual Load				**409,000 g/year**

a: Solids mass balance based on Lowe, *et al*. (2005) with several adjustments made to satisfy the chemical mass balance. See text for discussion. Conversion of sediment volume to sediment mass as given by Loewe, *et al*., 2005.
b: Mercury concentrations represent average surface sediment concentrations for 1991 to 1995 sediments.
c: CSO = Combined sewage overflow; WWTP = Waste water treatment plant
d: UK = unknown value. Mass fluxes for sources within unknown values were set to zero for the chemical mass balance.

This initial data evaluation suggests the occurrence of one or more unknown sources to account for the "missing" mercury; however, no source has been clearly identified. While a known potential source exists in Berry's Creek, a tributary on the Hackensack River, this source has been accounted for in estimates of mercury loads from the Hackensack, which are relatively minor (Table 4-9). Moreover, while the depositional history of mercury in the Lower Passaic River and Berry's Creek are temporally coincident (Weis & Weis, 2003; Weis & Weis, 2000), concentration gradients in the Hackensack River do not suggest that mercury from Berry's Creek is being substantively transported to Newark Bay. A currently undefined potential mercury source is Pierson's Creek, a manmade ditch draining into Newark Bay. The Troy Chemical Company, Inc. located on Pierson's Creek, processed mercury from 1956 to the late 1980s. In 1979, an estimated 300 pounds of mercury per day were discharged into the sanitary sewer system, which eventually drained into Newark Bay (NJDEP, 2002). However, more data are

necessary to examine the impact of Pierson's Creek on Newark Bay and identify other possible sources.

For all three mass balances (2,3,7,8-TCDD, Total TCDD, and mercury), the contribution by atmospheric fallout was assumed to be negligible. This assumption is reasonable given the magnitude of the solids flux from fallout and the likely range of contamination on particle fallout. By way of example, the contaminant concentration on the atmospheric solids would have to be 100 times greater than that found in Lower Passaic River sediments for the flux to match that of the Passaic. Similarly, the mercury and 2,3,7,8-TCDD contributions from CSO/WWTP discharges are not well known. However, unlike the atmospheric fallout, the solids flux from CSO/WWTP discharges is more substantial. While no data were found to constrain the mercury contribution form CSO/WWTP discharges (and indeed some of the missing mercury may come from CSO/WWTP discharge), the contributions by CSO/WWTP discharges from to the 2,3,7,8-TCDD balance are unlikely to be large. This assumption is based on work by Chaky (2003), who examined 2,3,7,8-TCDD discharges from the Newtown Creek WWTP, one of the largest water treatment plants in the metropolitan area. The 2,3,7,8-TCDD concentrations on Newtown Creek WWTP solids were on the order of 0.01 to 0.015 µg/kg, 50 times smaller than the concentrations on Lower Passaic River sediments. Given the estimated flux of solids from CSOs and WWTPs, it does not appear that they are a major contributor of 2,3,7,8-TCDD to Newark Bay.

4.6.3   MASS BALANCE SUMMARY

Table 4-10 provides a summary of the mass balance analyses on a percentage basis to aid in the assessment of the major loads to Newark Bay. Results are presented graphically in Figure 4-25 [including the solids mass balance presented by Lowe *et al*. (2005)].

Table 4-10: Mass Balance Contributions as Percentages

Source	Revised Solids (percent)	2,3,7,8-TCDD (percent)	Mercury (percent)
Passaic River	10	80	20
Hackensack River	2	3	4
CSO/WWTP [a]	3	UK	UK
Atmospheric Deposition	Negligible	Negligible	Negligible
Kill van Kull	70	8	30
Arthur Kill	15	8	9
"Missing" Mercury	NA[b]	NA[b]	35
Total[c]	100	~100	~100

a: Contaminant concentrations on CSO and WWTP loads for the Lower Passaic River were not available for the chemical mass balance calculations. However, measurements on Newtown Creek discharges would suggest that the contribution for 2,3,7,8-TCDD is minor (Chaky, 2003) and on the order of the contributions by the Hackensack River.
b: Not applicable to solids and 2,3,7,8-TCDD mass balances.
c: Columns do not sum to exactly 100 percent in all cases due to rounding. Percent contributions were rounded to nearest increment of 5 percent for contributions greater than 10 percent.

Two of the pie charts (Figure 4-25) depict solids mass balance estimates, one representing the original estimate by Lowe, *et al*. (2005) and one representing the updated balance developed in Section 4.6.1 (Table 4-7). In both presentations, the Kills clearly remain the major contributors of solids to Newark Bay. The updated solids mass balance indicates that the contribution of solids from the Lower Passaic River is approximately 10 percent of the total solids accumulating in Newark Bay (approximately 340,000 cubic yards; Table 4-7). Note that the requirement of a larger load from the Lower Passaic River does not negate the bathymetry-based observations made in Section 3.3 (Table 3-3). Rather, it is likely that uncertainties in the bathymetric observations and, in particular, those associated with the suspended solids delivery at the head of tide can easily accommodate the solids requirements dictated by the chemical mass balances. Notably, due to difficulties in capturing high flow-high suspended solids events, total annual solids loads are often difficult to determine accurately.

Unlike the Kills, which is the dominant source of solids, the Lower Passaic River is the dominant source for 2,3,7,8-TCDD, delivering on the order of 80 percent of the total load. No other source delivers more than 10 percent of the total 2,3,7,8-TCDD load to Newark Bay. For mercury, the Kill van Kull is the largest known source of mercury, representing about 30 percent of the total mercury load, but Kill van Kull source is still smaller than the missing mercury source, which delivers approximately 35 percent of the total mercury load. The Lower Passaic River is the third most important mercury source, contributing approximately 20 percent of the total mercury load. The importance of the missing mercury source is clearly evident in this depiction.

In summary, the results of these analyses show that Newark Bay is essentially a mixing bowl where large volume of solids delivered by the Kill van Kull are mixed and sullied with the smaller, but much more contaminated sources, on the perimeter of the bay. The following conclusions and observations summarize the chemical mass balance section.

- Concurrent solids mass balance for 2,3,7,8-TCDD and Total TCDD resulted in a revised solids mass balance [relative to the Lowe *et al*. (2005)] for Newark Bay where the solids from the Lower Passaic River comprise approximately 10 percent of the total amount of solids accumulating in the bay.
- Mass balance results for 2,3,7,8-TCDD indicate that currently more than 80 percent of the 2,3,7,8-TCDD accumulating in Newark Bay must originate in the Lower Passaic River. No other single source delivers more than 10 percent of the total 2,3,7,8-TCDD load.
- The mercury mass balance shows that, despite the high mercury concentrations located in the Lower Passaic River relative to Newark Bay, the Lower Passaic River is responsible for approximately 20 percent of the total mercury load to the bay. Moreover, the known sources of mercury to the bay cannot account for the annual accumulation of mercury in the sediment beds of Newark Bay. The "missing" mercury source represents the largest single "source" of mercury to the bay, constituting approximately 35 percent of the annual mercury load. The next largest "source" is the solids delivered by the Kill van Kull, which represent about 30 percent of the annual mercury load to Newark Bay. Note that these percentages are subject to

revision when more data for Newark Bay, the Arthur Kill, and the Kill van Kull become available. Nonetheless, a large source of mercury to Newark Bay remains unknown.

- The estimated current (*circa* 1995) total annual loads of mercury and 2,3,7,8-TCDD to Newark Bay are approximately 400 kilogram/year and 14 gram/year, respectively.

4.7   WATER COLUMN AND BIOTA EVALUATIONS

The sediment geochemistry evaluation provides information on historical loadings and sources of contaminants. To supplement this sediment evaluation, historical water column data were reviewed by HydroQual, Inc. (2005b; Appendix C), and historical biota data were reviewed by Battelle, Inc. (2005b; Appendix D). In general, the evaluations of water column and biota data were hindered by either a limited amount of data, undefined datasets, or data variability. For example, water column data were available in the project database and through the Contaminant Assessment Reduction Program (CARP). However, while the project database included more historical data than CARP, only the CARP data clearly define corresponding dissolved-phase and suspended-phase samples. Unfortunately, the CARP data are limited to 1998-2000 time period and five sampling locations.

Meanwhile, both the project and CARP databases contain information on a suite of species and corresponding tissue concentrations. However to focus the biota evaluation, select species and select chemicals were evaluated. The criteria for selection were: what data were available for each species, during what portion of their life cycle does each species reside in the Lower Passaic River, and what trophic level does the species populate. Based on these criteria, blue crab, mummichogs, and white perch were selected because they are resident species, they occupied different trophic levels, and data were available for the evaluation (majority of biota data were collected from 1998-1999 from RM 0 to 7). Multiple biota samples were collected and analyzed at each sampling location. As a result, tissue concentrations are scattered, reflecting natural variability and the impact of mobility on the dataset.

Despite the issues discussed above, some important observations that were assembled during this exercise include:

- Scatter plots presented in Figure 4-14 suggest that sediments (0-0.5 foot) from RM 1 to 7 are homogeneous, which likely resulted from tidal mixing and the resuspension of solids. Meanwhile, plots by HydroQual, Inc. for mercury, lead, Total PCB, Total PAH, and Total DDT show that suspended-phase concentrations approximated surficial sediment concentrations (0-0.1 cm), respectively, likewise implying that resuspension is likely influencing sediment homogeneity (Appendix C).
- Once resuspended in the water column, solids may impact water quality due to the partitioning of chemicals from the sorbed phase to the dissolved phase. The ratios of contaminant concentration in the suspended-phase to the dissolved-phase (units of µg/kg/µg/L) were calculated from plots by HydroQual. In general, the suspended solids were more contaminated than the dissolved-phase. For example, the ratio for the organic chemicals examined ranged from 10^5 for Total PCB to $10^{6.5}$ for 2,3,7,8-

TCDD, while the ratio for lead and mercury was 10^6 to 10^7. These ratios are, however, approximate due to data variability and small sample sizes ranging from 2 to 14 data points (Appendix C).

- The ratio of 2,3,7,8-TCDD/Total TCDD for surface sediment in the Lower Passaic River was reported as 0.7 ±0.1 [refer to the *Preliminary Geochemical Evaluation* (Malcolm Pirnie, Inc., 2005)]. If surface sediments are being resuspended and analytes are distributing to the water column, then it is anticipated that water quality and potentially biota will reflect a similar 0.7 ratio for 2,3,7,8-TCDD/Total TCDD. Indeed, HydroQual, Inc. showed that the suspended-phase and dissolved-phase constituents have a 2,3,7,8-TCDD/Total TCDD ratio of approximately 0.5 to 0.8 while Battelle, Inc. showed that blue crab tissue had a ratio of approximately 0.6 to 0.9. Mummichog and white perch had a ratio close to 1 for all samples. This value is similar to, but higher, than the typical range of the ratio observed in the sediments. (Note that the value of 1 may reflect potential analytical interferences or a preferential elimination of other forms of 2,3,7,8-TCDD in mummichog and white perch.)

- The presence of other contaminants (mercury, lead, Total PCB, Total DDT, and Total PAH) in biological tissue of blue crab, mummichog, and white perch, implies that the sediments are impacting the ecosystem. In general, the blue crab had higher reported concentrations compared to the mummichog and white perch (note the appreciable scatter in the datasets). For example, Total DDT in blue crab ranged from nondetected concentration to 1,000 $\mu g/kg_{tissue}$ while Total DDT in mummichogs ranged from nondetected concentration to 100 $\mu g/kg$ (Appendix D).

In summary, contaminants that were characteristic of Lower Passaic River sediments were detected in biota samples, indicating the likelihood of ongoing biological impacts from the contaminated sediments. Measurements of 2,3,7,8-TCDD in blue crab revealed the diagnostic ratio of 2,3,7,8-TCDD/Total TCDD, which was observed in the sediments. (The ratio in mummichogs and white perch was close to 1, similar to, but higher than the typical range of the ratio observed in the sediments.) Meanwhile, water column measurements of suspended matter also revealed the same diagnostic ratio of 2,3,7,8-TCDD/Total TCDD. Lastly, the suspended matter concentrations of mercury, lead, Total PCB, Total PAH, and Total DDT were consistent with observations of surface sediments, further confirming the link between suspended matter in the water column and estuarine sediments.

5.0   VOLUME OF CONTAMINATED SEDIMENT

The following section discusses the results of several different approaches to estimate the volume of contaminated sediment in the Lower Passaic River (refer to Section 2.4 and Section 2.5 for methodology). These estimates provide important information for consideration in evaluating remedial alternatives as well as provide some perspective on the reservoir of contamination that may limit long term recovery of the river. Each calculation, or approach, has some associated uncertainty, leading to an estimated volume that may be either biased low or biased high. However, together, these approaches provide valuable information on the potential depth and volume of contaminated sediment. The approaches to estimate the volume of contaminated sediment include simple and complex geostatistical integration of physical sediment characteristics and a geochemical inventory analysis using MPA and the measured depth of contamination. In addition to these approaches, the proposed dredging model presented by NJDOT-OMR (2000) is also summarized. Results are presented in tabular format within the text while figures are attached to the document.

5.1   GEOSTATISTICAL APPROACHES

For the geostatistical approaches, the thickness of recent (*i.e.*, industrial era), fine-grained sediment was determined for the available geotechnical borings collected in 2005. The thickness was estimated from grain size classification, sediment texture, color, and associated field notes (refer to Table 2-6 for details). For this data evaluation, recent sediment deposits were classified as black-gray colored sediments whereas brownish-red colored sediment corresponded to older deposits. The analysis assumes the recent, fine-grained sediments thickness is approximately equal to the thickness of contaminated sediment.

In the first (and simpler) calculation, the average thickness of contaminated sediment was calculated from available geotechnical cores for each silt area as presented by Aqua Survey, Inc. (2005) based on side-scan sonar interpretation. The volume of sediment was then calculated as the area multiplied by the average thickness. The total volume of contaminated sediments is the sum of these volumes, or 4.6 million cubic yards of silt. Since silt extends from RM 0 to 15, this volume calculation of 4.6 million cubic yards represents contaminated silt for nearly the entire Lower Passaic River. As a first-order approximation, 75 percent of the silt area is located in RM 1 to 7, suggesting the volume of contaminated silt in this river section is 3.5 million cubic yards. (This evaluation considers only RM 1 to 7 to be consistent with the MPA evaluation and the discussion by NJDOT-OMR.)

The second (and more complex) geostatistical approach estimated the volume of contaminated sediment by interpolating a thickness for each area defined as silt or silt/sand sediment textures and then multiplying this thickness by the associated area. Sediment thickness was again based on the suite of geotechnical cores with an added assumption that the sediment thickness thins to zero at the river's edge. This assumption is derived from bathymetric observations, which suggest lower rates of sediment

accumulation at the river's edge. Figure 5-1 contains color-contoured maps of the river in plan view, illustrating the interpolated thickness of sediments as well as the location of the geotechnical borings. Note that the interpolated thickness is in units of centimeters (cm) and that the legend on the screen-shots changes. The lateral extent of the color contouring presented in Figure 5-1 represents the extent of the silt and silt/sand sediment classification zones as defined by side-scan sonar. An important observation is that while 76 geotechnical borings were available for this evaluation, the density of cores in any given river segment was small, resulting in large area with little or no depth data (essentially data gaps for this analysis), which affected the uncertainty in the interpolation. For example, geotechnical borings were collected at RM 2 and 3, but no data were available between these two points, forming a data gap. In the absence of data points, the assumption of zero sediment thickness at the river's edge begins to influence the sediment thickness in the middle of the river more than the borings at RM 2 and 3. The resulting interpolated thickness of sediments in this data gap is then estimated as 50-100 cm, which is likely biased low, based on the bathymetric examination showing high rates of sediment accumulation in the river channel. Table 5-1 summarizes the results from the interpolated geostatistical approach.

Table 5-1: Results of the Interpolated Geostatistical Approach

Parameter	RM 0 to 6 [a]	RM 6 to 15
Area Examined (miles^2)	0.6	0.3
Thickness Range (cm)	3 to 612	0 to 147
Average Thickness (cm)	137	47
Average Thickness (ft)	4.5	1.5
Volume (cubic yards)	2,800,000	460,000

a: Refer to Section 2.4.2 for details on interpolation and division of river miles.

The geostatistical approach resulted in 2.8 million cubic yards of contaminated sediment for RM 0 to 6, which is 86 percent of the total volume of contaminated sediment in the Lower Passaic River from RM 0 to 15. However, this volume estimate is likely biased low due to the interpolation of data across data gaps and influence by the boundary conditions. For example, the corresponding contaminated-sediment thickness was 4.5 feet for RM 0 to 6 (Table 5-1), which is shallow when considering that sediment cores reported detectable contaminant concentrations deeper than 4.5 feet (Section 4.3). Hence, as an alternative approach, sediment cores were then examined to estimate the volume of contaminated sediments using geochemistry.

5.2   MPA APPROACH

5.2.1   MPA CALCULATION AND POLYGONAL DECLUSTERING

The MPA values were calculated to estimate the sediment inventory for Total DDT, 2,3,7,8-TCDD, Total PCB, and mercury for RM 1 to 7. As discussed in Section 2.5, the MPA value represents the vertical integration of contaminant mass in the sediment at a specific coring location (g/m^2) and provides a basis to estimate the total contaminant mass over a selected area. Figures 5-2 through 5-5 present the results of the polygonal declustering for each contaminant, respectively. On each map, the polygon is color-coded to represent the corresponding MPA value for that polygon. One of the first

observations from these maps is that the polygon sizes varied substantially, suggesting variation in the density of coring locations. For example, one polygon at RM 3 extends from bank to bank, indicating a low sample density; however, adjacent to this polygon, at approximately RM 3.1, four polygons extend from bank to bank (the results of a cross-section of coring locations). The variation in sampling density is also illustrated in Figure 5-6, which shows the histogram of the number of cores for different river miles. This figure shows that most of the samples were collected between RM 3 and 4 while the fewest samples were collected between RM 6 and 7. The second observation from the MPA maps is that the data exhibit a great deal of short-range heterogeneity; that is, high contaminant inventory areas are often found immediately adjacent to low inventory areas.

Another feature on the MPA maps is that each core in the polygons is further classified by core types and depth of the contamination. The two different types of cores based on sampling techniques, continuous and discontinuous (or interpolated) segmentation, are represented by circle and triangle symbols, respectively. As described in Section 2.5.2, the cores were further grouped into three categories. A core with "contaminant with bottom concentration below reporting limit" is represented by the hollow symbol. A core with "contaminant concentration decreasing at depth" is represented by a half-filled symbol, and a core with "contaminant concentration elevated or increasing at depth" is represented by a filled symbol. The depth of contamination is shown by the size of the symbol, increasing with the depth of contamination. In general, the majority of the cores are relatively short and incomplete, suggesting that the cores did not penetrate deeply enough into the sediment bed to capture the thickness of contaminated sediment.

Table 5-2 presents a summary of core classifications for each of the four examined contaminants. The table shows that for each contaminant, only apportion of the cores fall into the least uncertain category ("bottom concentration below reporting limit"). For mercury, Total DDT, and 2,3,7,8-TCDD, the fraction of cores in this category was one third or less with 2,3,7,8-TCDD having only 21 percent of the total number of cores in this category. Only Total PCB yielded a large fraction of cores in the "bottom concentration below reporting limit" category, which is consistent with the dated core results that show Total PCB contamination to be consistently shallower than the other contaminants. As a result, this shallow inventory is captured by short cores. Meanwhile, nearly half of the cores for mercury and more than a third of the cores for Total DDT are grouped in the most uncertain category. Cores in this category have a high degree of uncertainty and are poor estimates of the depth of contamination.

Table 5-2: Core Categories for Estimation of Sediment Inventories

Core Category [a]	Total DDT Count [a] (percent)	2,3,7,8-TCDD Count [a] (percent)	Mercury Count [a] (percent)	Total PCB Count [a] (percent)
Bottom Concentration below reporting limit	41 (34 percent)	23 (21 percent)	32 (28 percent)	70 (61 percent)
Concentration decreasing at depth	36 (30 percent)	59 (54 percent)	28 (24 percent)	14 (12 percent)
Concentration elevated or increasing at depth	43 (36 percent)	27 (25 percent)	56 (48 percent)	30 (26 percent)
Total	120 (100 percent)	109 (100 percent)	116 (100 percent)	114 (100 percent)

a: See Section 2.5.2 for discussion of categories; core count based on 1991 and 1995 data

By summing the "contaminant concentration decreasing at depth" category and "contaminant concentration elevated or increasing at depth" category, incomplete cores can be discussed as a whole. For mercury, 2,3,7,8-TCDD, Total DDT, and Total PCB, approximately 72 percent, 79 percent, 66 percent, and 39 percent of the total number of cores, respectively, *did not* penetrate to a layer of uncontaminated sediment. Hence, the associated estimates of the contaminated sediment mass based on the available data will be biased low, representing a minimum volume estimate. (A basis to extrapolate the core results is discussed in Section 5.2.2.) Moreover, an integration of contaminant mass by core type, discussed in Section 5.2.2, will show that the uncertainty in the depth of contamination is greater than the uncertainty in the contaminated sediment mass because the two most uncertain core categories are associated with a disproportionate mass of the contaminants.

Before beginning the integration of the MPA values into mass and volume estimates, correlations between MPA values were examined, and MPA values were plotted against river mile to examine their spatial distribution. Figure 5-7 shows a plot of a weighted curve fit for the MPA values versus river mile. The weighted curve fits the data using the locally weighted Least-Squared error method. This curve provides a measure of the running mean of the data set as a function of river mile. In general, the MPA values for all four contaminants follow the same trend. Local maxima exist around RM 3 and RM 7 for all contaminants while high MPA values are evident for Total PCB and mercury around RM 1. The high MPA values for Total PCB and mercury, and the low MPA for Total DDT and 2,3,7,8-TCDD, may result from the combination of the high sediment depositional rate and the length of the cores collected in the area. Specifically, core maxima for Total PCB and mercury are typically shallower than those for Total DDT and 2,3,7,8-TCDD. Thus, relatively short cores combined with a high rate of deposition would yield cores with high inventories for shallow contaminants and low inventories for the deeper contaminants. Meanwhile, a local minimum MPA values exists from RM 5 to 6 for all contaminants. These observations suggest that the four contaminants are spatially coincident, suggesting that the MPA value for the analytes examined are correlated.

The correlation among contaminant inventories was further examined using a correlation matrix (Figure 5-8). A power curve was fitted to the data in each pairing, and the correlation coefficient (R) was displayed on each graph. The R value obtained represents a linear regression of the logs of MPA values. The strongest relationship is observed for 2,3,7,8-TCDD and Total DDT with a R value of 0.85 while 2,3,7,8-TCDD and Total PCB has the weakest relationship with R of 0.33. This regression analysis demonstrates that the analytes are qualitatively related to each other and that correlation was not intended as a quantitative predictive tool. Essentially, the analysis indicates that local inventory maxima of one contaminant are coincident with local inventory maxima for other contaminants, although the absolute magnitude of the MPA values may not be strictly correlated. For example, if one were to look at location with high mercury MPA, then most likely the MPA for 2,3,7,8-TCDD, Total PCB, and Total DDT are high as well.

To further evaluate the MPA calculations for 2,3,7,8-TCDD, the data presented in Figure 5-3 was compared to another study. The distribution of 2,3,7,8-TCDD in the Lower Passaic River was studied by Ma *et al*. (1998). Their work is presented in Figure 5-9, which shows a three-dimensional distribution of 2,3,7,8-TCDD. The figure also shows the MPA calculated for 2,3,7,8-TCDD that was originally presented in Figure 5-3. The highest 2,3,7,8-TCDD concentrations according to Ma *et al*. are located at a depth of 4-6 feet in the sediment beds at the mouth of the river and approximately RM 3. This observation occurs in part because the data in the three-dimensional analysis consists of core data restricted to a depth of 6 feet or less. In contrast, the MPA evaluation discussed in this document uses the whole length of the core. Although the MPA map (Figure 5-3) shows a two-dimensional projection, high MPA areas clearly extend over wider areas along the river relative to the analysis by Ma *et al*., indicating that many of the cores have maximum or high concentrations below 6 feet.

5.2.2 TOTAL CONTAMINANT MASS

The total contaminant mass (RM 1 to 7) was then estimated by multiplying each polygon area by the associated MPA value and summing the product. Table 5-3 shows the total contaminant mass sorted by sediment texture. In general, more than 80 percent of the total contaminated mass is included in the silt sediment texture category.

Table 5-3: Total Contaminant Mass Sorted by Sediment Texture

Sediment Texture	Total DDT Mass (kg) [a]	2,3,7,8-TCDD Mass (kg) [a]	Mercury Mass (kg) [a]	Total PCB Mass (kg) [a]
Coarse Material	150	1.4 [b]	2,700	500 [b]
Sand	4.0 [b]	0.92 [b]	130 [b]	67 [b]
Silt/Sand	150	0.88	1,200	430
Silt	6,100	17	20,000	5000

a: MPA calculation covers RM 1 to 7; values rounded to two significant figures
b: MPA calculation based on less than two data points

Alternatively, the total contaminant mass was sorted based on the core classifications (Table 5-4). The results show that for each contaminant, except Total PCB, the contaminant mass is disproportionately associated with the more uncertain core categories ("contaminant concentration decreasing at depth" and "contaminant concentration elevated or increasing with depth"), indicating that the overall mass estimates are biased low. In all cases, the mass represented by these uncertain core categories is over half of the total inventory, supporting the likelihood that the integration of these cores will yield a low-end estimate for the contaminant inventories and contaminated sediment volume.

Table 5-4: Total Contaminant Mass Sorted by Core Classification

Core Classification	Total DDT Mass (kg) and Percent [a]	2,3,7,8-TCDD Mass (kg) and Percent [a]	Mercury Mass (kg) and Percent [a]	Total PCB Mass (kg) and Percent [a]
Bottom Concentration below reporting limit	190 (3.0 percent)	0.7 (3.6 percent)	6,300 (27 percent)	2,900 (48 percent)
Concentration decreasing at depth	2,300 (36 percent)	14 (69 percent)	6,000 (25 percent)	990 (16 percent)
Concentration elevated or increasing at depth	4,000 (62 percent)	5.4 (28 percent)	11,000 (48 percent)	2,200 (36 percent)

a: MPA calculation covers RM 1 to 7; values rounded to two significant figures

Among the contaminants, the concern of a low-end estimate is greatest for Total DDT because 62 percent of the Total DDT mass is associated with incomplete cores having elevated or increasing concentrations at depth. This situation implies that a substantial inventory of contaminant mass is likely located below the core bottoms. Approximately 30 percent of the total number of cores were complete (*e.g.*, they penetrated into uncontaminated sediment); however, these complete cores only accounted for 3 to 4 percent of the total mass for Total DDT and 2,3,7,8-TCDD. Meanwhile, mercury and Total PCB had a greater percentage of contaminated mass that was associated with cores that penetrated into uncontaminated sediment (*i.e.*, "bottom concentrations below reporting limit"), but the contaminant mass was still less than half the total mass estimate.

An alternative approach to evaluating the total contaminant mass is to estimate an average contaminant concentration in the sediment. This average, called the "volume-weighted average concentration" is equal to the total contaminant mass divided by the volume of sediment and the sediment density. Table 5-5 shows the volume-weighted average concentrations for different sediment texture and core classifications. Similar to results in Table 5-3, volume-weighted average concentrations are high for the silt areas. Note that the mercury and Total PCB concentrations in the sand area are high, but these concentrations were based on one or two data points. Likewise, the volume-weighted average concentrations are high for the cores with "contaminant concentration elevated or increasing at depth," as expected based on the results of Table 5-4

Table 5-5: Volume-weighted Average Concentrations

Sediment Texture	Total DDT (mg/kg) [a]	2,3,7,8-TCDD (mg/kg) [a]	Mercury (mg/kg) [a]	Total PCB (mg/kg) [a]
Coarse Material	0.37	0.0071	4.3	3.9
Sand	0.29	0.0042	9.8	4.9
Silt/Sand	0.54	0.0032	4.6	2.4
Silt	2.8	0.0070	8.0	2.8

Table 5-5 (Continued)				
Core Classification	**Total DDT (mg/kg)**	**2,3,7,8-TCDD (mg/kg)**	**Mercury (mg/kg)**	**Total PCB (mg/kg)**
Bottom Concentration below reporting limit	0.28	0.0010	8.3	2.4
Concentration decreasing at depth	2.0	0.0077	5.4	3.4
Concentration elevated or increasing at depth	4.0	0.011	7.6	3.6

a: MPA calculation covers RM 1 to 7; values rounded to two significant figures

Because the majority of the cores had bottom segments that were greater than the analyte-specific criterion, a larger degree of uncertainty is associated with contaminant inventory and the actual depth of concentration. To account for this uncertainty, the sediment inventories (presented in previous tables) were extrapolated. For the cores with "contaminant concentrations decreasing at depth" the sediment inventory was increased by 25 percent since the actual depth of contamination is not expected to extend much beyond the sampling length of the core. The cores with "contaminant concentrations elevated or increasing at depth" are more uncertain, so the sediment inventory was doubled. Note that the multiplying of the contaminant volume by the extrapolation factor for each core category (*i.e.,* 1.25 for cores with "contaminant concentrations decreasing at depth" and 2 for cores with "contaminant concentrations elevated or increasing at depth") is equivalent to multiplying the depth of contamination for each core by the factor, and then, re-integrating to determine total sediment volume. The added volume is assumed to have the same mean concentration as the measured inventory, so the contaminant mass for each core category increases proportionately as well. Table 5-6 compares the original average depth of contamination and volume of contamination with the extrapolated depth, extrapolated mass, and extrapolated volume for the four contaminants. Note that because of the assignment of extrapolation factors, the most uncertain cores ("contaminant concentrations elevated or increasing at depth") contribute a larger fraction of the total contaminant mass and volume of sediment for the extrapolated estimates.

Table 5-6: Extrapolated Depth of contamination, Contaminant Mass, and Sediment Volume

Analyte	Average Depth of Contamination (feet) a	Volume of Sediment (cubic yards) a	Extrapolated Depth of Contamination (feet)[a,b]	Extrapolated Contaminant Mass (kg) [a,b]	Extrapolated Volume of Sediment (cubic yards) [a,b]
Total DDT	7.4	4.5 million	11	11,000	6.6 million
2,3,7,8-TCDD	8.0	4.9 million	11	29	6.5 million
Total PCB	5.7	3.5 million	7.6	8,000	4.7 million
Mercury	8.6	5.3 million	13	37,000	8.0 million

a: MPA calculation covers RM 1 to 7; values rounded to two significant figures
b: Extrapolated values calculated by increasing the depth by 25 percent for "contaminant concentrations decreasing at depth" and doubling the depth for "contaminant concentrations elevated or increasing at depth."

Based on geochronology, peak concentration of Total DDT are expected to occur deeper in a sediment core than 2,3,7,8-TCDD (Section 4.3.4). However, Table 5-5 shows that the average depth of 2,3,7,8-TCDD contamination is deeper than that Total DDT. This

apparent reversal is attributed to the different sensitivity analyte-specific criterion (Table 2-9). The criterion for 2,3,7,8-TCDD is 0.002 µg/kg and 10 µg/kg for Total DDT. If the analytical procedure for DDT had the same sensitivity as 2,3,7,8-TCDD, the comparable criteria for Total DDT would be approximately 0.8 µg/kg. However, the data show that the smallest nondetected value was approximately 1.8 µg/kg with 95 percent of the nondetected values below 10 µg/kg. As a result, the data suggest that 2,3,7,8-TCDD is deeper than DDT; however, after accounting for uncertainties in the cores, the average extrapolated depth of 2,3,7,8-TCDD and Total DDT is about the same (11 feet). In addition, because of the different analytical procedures sensitivity, the core classification of the Total DDT and 2,3,7,8-TCDD cannot be compared directly in the two MPA maps (Figures 5-2 and 5-3).

5.2.3 MPA SUMMARY

The following conclusions and observations summarize the MPA analysis.

- A review of the available coring data for the Lower Passaic River (RM 0.9 to 7.0) revealed that most cores did not establish the actual depth of contamination for several major contaminants, including 2,3,7,8-TCDD, Total DDT, and mercury. For each contaminant examined, no more than one third of the cores penetrated to a depth where contaminant concentrations were considered equal to, or close to, background levels. Only the Total PCB dataset contained a majority of cores (60 percent) that penetrate to background levels.
- In total, 50 to 98 percent of the estimated mass of 2,3,7,8-TCDD, Total DDT, and mercury occurs at coring sites that did not reach background levels at the core bottom.
- For the remaining cores used in the MPA analysis, 25 to 48 percent of the available cores, depending on contaminant, were considered uncertain with respect to the depth of contamination (*i.e.*, concentration trends that increased with depth.)
- Two inventory estimates were generated for the mass of each of four contaminants in the Lower Passaic River. The first estimate was based on an interpolation of core measurements; the second was based on the extrapolation of the core measurements when the core did not establish the depth of contamination. The interpolated volume is considered a minimum estimate due to the uncertainties in depth of contamination. The extrapolated inventory represented an increase of 33 to 72 percent over the interpolated estimate (Table 5-7).

Table 5-7: Summary of Contaminant Inventory Estimates

Inventory Estimate [a]	Total DDT (Metric ton) [b]	2,3,7,8-TCDD (kg) [b]	Mercury (Metric ton) [b]	Total PCB (Metric ton) [b]
Interpolated	6.4	20	24	6
Extrapolated	11	29	37	8
Percent Increase [c]	72 percent	45 percent	54 percent	33 percent

a: See text for discussion
b: Estimates rounded to two significant figures (when appropriate); 2,3,7,8-TCDD is in units of kilograms
c: Percent increase is relative to the interpolated mass estimate

- Inventories of the four contaminants were shown to correlate, indicating that contaminant inventories coincide in space and consistent with the anticipated geochemical behavior of the compounds. Essentially, when a location has a locally high inventory of any one contaminant, the other contaminants will also be concentrated at that location.
- Contaminant inventories vary along the length of the Lower Passaic River with maximum values occurring near RM 1 to 2, RM 3 to 4, and RM 6 to 7. However, the coring data indicates a high degree of spatial heterogeneity, suggesting that localized areas of relatively higher concentrations typically described as "hot spots" do not exist. Instead, "hot" regions of the river typically exist on the scale of a mile or more, nearly bank to bank in lateral extent.

5.3   NJDOT-OMR MODEL

The calculations, presented in Section 5.1 and Section 5.2, represent new estimates of the volume of contaminated sediment using several different approaches. Prior to this work, an estimate of the sediment volume was prepared by the NJDOT-OMR. Their basic approach is described here (Section 5.3) for comparison. To estimate the volume of dredged material for removal, the NJDOT-OMR examined historical concentrations of 2,3,7,8-TCDD (collected from 1984 to 1995). By examining the magnitude of 2,3,7,8-TCDD concentrations in the cores, NJDOT-OMR estimated a conservative depth of contaminated sediment. This depth was then multiplied by an anticipated dredging length and width to calculate an estimated volume of dredged material. Their criterion for sediment restoration was 0.03 μg/kg of 2,3,7,8-TCDD, since this concentration yields 1 μg/kg or greater bioaccumulation of 2,3,7,8-TCDD in sandworms (NJDOT-OMR, 2000). A summary of dredging depths include:

- From RM 0.9 to 2.2 (Point No Point Reach), the maximum level of 2,3,7,8-TCDD contamination was located 4 feet deep. Since 2,3,7,8-TCDD was still detected at 14 feet (0.52 μg/kg), but not at 15 feet, a dredging depth of 16 feet was selected.
- From RM 2.2 to 4.3 (Harrison Reach), the maximum level of 2,3,7,8-TCDD contamination was located 5 feet deep. Since 2,3,7,8-TCDD was still detected at 17 feet (0.051 μg/kg) along with relatively high levels of mercury (7.8 mg/kg), a dredging depth of 19 feet was selected.
- From RM 4.3 to 5.8 (Newark Reach), the maximum level of 2,3,7,8-TCDD contamination was located 10 feet deep. Since no data were available beyond 10 feet (2,3,7,8-TCDD concentrations of 32 μg/kg), a conservative dredging depth of 15 feet was selected.
- From RM 5.8 to 6.8 (Kearny Reach), the maximum level of 2,3,7,8-TCDD contamination was located 2 feet deep. Since no data were available beyond 7 feet (2,3,7,8-TCDD concentrations of 0.005 μg/kg), a conservative dredging depth of 10 feet was selected.
- Beyond RM 6.8 (Arlington Reach), the maximum level of 2,3,7,8-TCDD contamination was located 2 feet deep. Since 2,3,7,8-TCDD was still detected at 4 feet (0.031 μg/kg), a conservative dredging depth of 10 feet was selected.

An estimated volume of dredged material for removal was then calculated from these estimated dredging depths. This approach resulted in 10 million cubic yards of sediment for RM 1 to 7. Note that this volume may be substantially overestimated because of (1) the conservative dredging depths and (2) the assumption that the depth of contamination is consistent across each river reach (NJDOT-OMR, 2000).

5.4   SUMMARY OF VOLUME OF CONTAMINATED SEDIMENTS

Estimates for the volume of contaminated sediments ranged from 2.8 to 8 million cubic yards for the RM 1 to 7 region of the Lower Passaic River. (The average depth of contamination ranged from 4.6 to 13 feet.) Estimated volumes can be further contrasted with the volume estimate of 10 million cubic yards prepared by NJDOT-OMR. These estimates were based on several different approaches with the highest volumes coming from the extrapolation of contaminant concentrations and the lowest volumes interpolated from geotechnical borings (Table 5-8). In general, the current "best estimate" on the volume of contaminated sediment is 5 to 8 million cubic yards derived from the MPA approach, which was the best supported approach in term of data. However, additional investigation is required to further narrow the range of the volume estimate.

Table 5-8: Summary of Volume of Contaminated Sediment

Approaches	River Mile	Sediment Type	Volume of Contaminated Sediment
Geostatistical Approach – Average Depth	RM 1 to 7	Silt	3.5 million
Geostatistical Approach – Interpolated Depth	RM 0 to 6	Silt and Silt/Sand	2.8 million
MPA-Based Calculation using Total PCB	RM 1 to 7	All textures [a]	3.5 to 4.7 million
MPA-Based Calculation using 2,3,7,8-TCDD	RM 1 to 7	All textures [a]	4.9 to 6.5 million
MPA-Based Calculation using Total DDT	RM 1 to 7	All textures [a]	4.5 to 6.6 million
MPA-Based Calculation using Mercury	RM 1 to 7	All textures [a]	5.3 to 8.0 million
NJDOT-OMR Model [b]	RM 1 to 7	Dredge Material	10 million

a: All sediment textures include: silt, silt/sand, sand, and coarse material
b: Reference: NJDOT-OMR, 2000

6.0   CONCLUSIONS AND OBSERVATIONS

The geochemical evaluation presented in this document forms the basis for an important series of conclusions and observations regarding the complexities of the Lower Passaic River as well as the usefulness of the existing database to describe the river. These conclusions and observations should be viewed as important initial findings to be further explored and verified by the analysis of the fall 2005 data collection efforts as well as the ongoing modeling analyses. The conclusions and observations below are listed by general topic without assigning a relative level of importance:

Sediment Transport and Deposition (Section 3.0)

- Sediment accumulation in the Lower Passaic River is dynamic with some relatively large swings in annual accumulation as suggested by a series of bathymetric surveys. Annual sediment deposition averaged approximately 70,000 cubic yard/year between 1989 and 2004, which is roughly equivalent to one inch of sediment accumulation over the Lower Passaic River bottom (RM 0 to 17) or 1.5 inches over the lower 7 miles. Approximately 90 percent of this accumulation occurs in the RM 0 to 7. Area-averaged deposition rates were consistent with those rates obtained from dated sediment cores collected from the same areas.
- The largest sediment transport events were roughly equivalent to 2 inches of loss or gain of sediment over the entire river bottom although most years exhibited a net gain of sediment.
- A detailed examination of sediment deposition rates in the Lower Passaic River (RM 0 to 7) indicates a high degree of spatial heterogeneity with local rates varying from about -6 inch/year of erosion to about +8 inch/year of deposition. However, annual accumulation values and average sedimentation rates suggest that the Lower Passaic River (RM 0 to 7) is primarily depositional with the highest deposition rates occurring in RM 0 to 1.
- While the Lower Passaic River is experiencing a net deposition of sediment, a solids mass balance indicates that upriver solids are transported through the Lower Passaic River into Newark Bay, and potentially beyond. Estimates suggest that 20 to 50 percent of the upriver solids are eventually transported out of the Lower Passaic River.

Contaminant Chronologies (Section 4.3)

- Consistent with the observations by Bopp *et al.* (1991a) and Chaky (2003) for Newark Bay, dated sediment cores for the Lower Passaic River (RM 1 to 7) show that the major releases of 2,3,7,8-TCDD begin in the 1950s and peak in the early 1960s.
- The diagnostic ratio of 2,3,7,8-TCDD/Total TCDD of 0.7 to 0.8 can be used to trace Lower Passaic River PCDD throughout the Newark Bay complex and over the last 60 years. Based on dated sediments cores, this diagnostic ratio is observed throughout the sediments of the Lower Passaic River as far back as the 1950s. The ratio of

2,3,7,8-TCDD/Total TCDD prior to 1950 is characteristic of sewage and atmospheric fallout (less than 0.05).

- Dated sediment cores reveal that Total DDT discharges to the Lower Passaic River begin in the 1930s and peaking in the late 1940s or early 1950s, which is consistent with the observations of Bopp *et al.* (1991a). Results consistently show measurable Total DDT concentrations occurring deeper in the sediment core than measurable 2,3,7,8-TCDD concentrations, suggesting the possible application of DDT as a measure of the vertical extent of 2,3,7,8-TCDD contamination. However, there may be some limitations to the usefulness of Total DDT in this regard due to measurement sensitivities for Total DDT.
- Major contamination of the Lower Passaic River likely occurred in the 1930s and earlier. Elevated concentrations of arsenic (approximately 60 mg/kg), chromium (approximately 800 mg/kg), copper (approximately 700 mg/kg), lead (approximately 700 mg/kg), Total PAH (approximately 100 mg/kg), and benzo[a]pyrene (approximately 14 mg/kg) occur at depth in dated sediment cores, usually reaching a maximum at core bottoms. This evidence indicates that the vertical extent of these contaminants is undefined and that major inventories of these contaminants most likely lie below the documented depth of 2,3,7,8-TCDD contamination.
- Dated sediment cores were also insufficient to establish the depth of contamination for mercury and cadmium although peak concentrations (approximately 15 and 25 mg/kg, respectively) appear to have occurred in the 1960s, concurrent with the 2,3,7,8-TCDD maximum.
- PCB is found throughout the Lower Passaic River with peak values (4 to 18 mg/kg) occurring at a depth corresponding to the 1960s. Aroclor 1248 is the most commonly reported PCB mixture, typically comprising 60 percent or more of the Total PCB burden.
- An examination of Total DDT to 2,3,7,8-TCDD concentrations downcore indicted that ratio analysis was unlikely to be productive and so was not pursued.

Surface Sediment Concentrations (Section 4.4)

- Dated sediment cores from the Upper and Lower Passaic River were used to differentiate the source regions for several major contaminants. These cores suggest that the major historical loads of cadmium, lead, mercury, and Total PCB primarily originated in the Upper Passaic River above the Dundee dam. A substantial load of copper also originated above the Dundee Dam, but an additional load was also present downriver. Smaller contaminant sources, particularly mercury, may also have existed in the Lower Passaic River (RM 0.9 to 7.0).
- Dated sediment cores from the Upper and Lower Passaic River further indicate that relatively little of the Total DDT and much less than 1 percent of the 2,3,7,8-TCDD contamination in the Lower Passaic River originated above the Dundee Dam historically.
- An examination of the 1995 surface sediments in the Lower Passaic River suggests that at least two sources for arsenic, chromium, and mercury are present (one at or below RM 1 and one at or above RM 7). Dated sediment cores show a similar

condition for arsenic and mercury in 1963. The likely upriver mercury source is the one originating upriver of the Dundee Dam.

- Surface sediment data in the RM 3 to 4.5 region had a relatively high frequency of outlier values, occurring across the contaminants, suggesting that this region may have a number of locations undergoing erosion and exposing older, more contaminated sediments. The consistent occurrence of these outliers across all contaminant types tends to rule out the possibility of an ongoing local source since it would need to include all of the major contaminants. This conclusion requires further evaluation.

- Ratio analysis of metal contamination in the Lower Passaic River (RM 0.9 to 7.0) showed little variation in the metals pattern. Analysis of surface metal concentrations also showed relatively little trend with river mile. This evidence demonstrates the homogeneity of surficial sediments in the Lower Passaic River and suggests that tidal mixing is able to homogenize local metals loads over long distances, prior to the deposition of the contaminants in the river bottom.

- Organic contaminant concentrations in the Lower Passaic River were generally not as homogeneous as the metal concentrations. Nonetheless, few trends were apparent with river mile (only Total PAH exhibited a trend), again suggesting extensive tidal mixing of suspended matter prior to settling and storage as river sediments.

Source Analysis (Section 4.5)

- The examination of surface sediment and dated sediment cores located above and below Dundee Dam indicates that concentrations of examined contaminants have declined everywhere to some degree relative to 1963 conditions.

- An examination of metal ratios in dated sediment cores and surface sediment samples further supports the origin of Lower Passaic River cadmium, lead, and mercury contamination above the Dundee Dam.

- In 1995, metals concentrations above the Dundee Dam for cadmium, lead, and mercury are comparable in magnitude to their concentrations downriver. This observation further supports the conclusion that the Upper Passaic River continues to be responsible for much of the cadmium, lead, and mercury contamination in the Lower Passaic River.

- In 1963, the Total PCB source upriver of the Dundee Dam accounted for the majority of the Total PCB load in the Lower Passaic River. However, evidence suggests that currently (*circa* 1995), the Upper Passaic River Total PCB source has become less important relative to Lower Passaic River Total PCB load. Nevertheless, the Upper Passaic River source may still comprise one third of the Total PCB loading in the Lower Passaic River.

- Total DDT loads from the Upper Passaic River remain relatively small as compared to the Lower Passaic River loads with the Upper Passaic River contributing perhaps one quarter of the Total DDT input.

- The Upper Passaic River remains a trivial source of 2,3,7,8-TCDD to the Lower Passaic River despite the passage of time. The Upper Passaic River is unlikely to represent more than 2 percent of the total loading to the Lower Passaic River.

- Ratio analysis of 2,4′-DDT and 4,4-DDT and their metabolites did not yield a diagnostic ratio for the surface sediments of the Lower Passaic River. The ratio was similar to the signature of agriculturally applied DDT. No data were available to examine deeper sediments.
- Ratio analysis of Total PAH shows that the majority of sediment contamination is derived from combustion-related processes. The ratio "fingerprint" suggests that Total PAH originates from two sources coal tar residue (a by-product of manufactured gas plants) and urban background combustion. Of these two sources, coal tar wastes are the dominant source based on the prevalence of coal tar-like PAH ratios in the sediments. The same analysis essentially rules out creosote-derived contamination and suggests only minor portions of the sediment PAH contamination are derived from a petrogenic source.
- The principal components analysis shows the occurrence of occasional petroleum-based PAH contamination distributed randomly throughout the Lower Passaic River. This observation is supported by the pervasive level of TPH (100 to 1,000 mg/kg) found throughout the Lower Passaic River (RM 0.9 to 7.0).
- There is no basis available to estimate loads from the Upper Passaic River prior to 1963 and only a limited basis to estimate them post 1963. This situation represents a significant data gap given the evidence for the importance of the Upper Passaic River source.
- These source analyses and the previous subsections of Section 4.0 underscore the importance of investigating the contaminant chronology at the Dundee Dam, given the loads that continue to originate there.

Chemical Mass Balance (Section 4.6)

- Concurrent solids mass balance for 2,3,7,8-TCDD and Total TCDD resulted in a revised solids mass balance [relative to the Lowe *et al*. (2005)] for Newark Bay where the solids from the Lower Passaic River comprise approximately 10 percent of the total amount of solids accumulating in the bay.
- Mass balance results for 2,3,7,8-TCDD indicate that currently more than 80 percent of the 2,3,7,8-TCDD accumulating in Newark Bay must originate in the Lower Passaic River. No other single source delivers more than 10 percent of the total 2,3,7,8-TCDD load.
- The mercury mass balance shows that, despite the high mercury concentrations located in the Lower Passaic River relative to Newark Bay, the Lower Passaic River is responsible for approximately 20 percent of the total mercury load to the bay. Moreover, the known sources of mercury to the bay cannot account for the annual accumulation of mercury in the sediment beds of Newark Bay. The "missing" mercury source represents the largest single "source" of mercury to the bay, constituting approximately 35 percent of the annual mercury load. The next largest "source" is the solids delivered by the Kill van Kull, which represent about 30 percent of the annual mercury load to Newark Bay. Note that these percentages are subject to revision when more data for Newark Bay and the Kills become available. Nonetheless, a large source of mercury to Newark Bay remains unknown.

- The estimated current (*circa* 1995) total annual loads of mercury and 2,3,7,8-TCDD to Newark Bay are approximately 400 kilogram/year and 14 gram/year, respectively.

Water Column and Biota Evaluations (Section 4.7)

- Water column measurements of suspended matter revealed the same diagnostic ratio of 2,3,7,8-TCDD/Total TCDD observed in the sediments, confirming the anticipated link between suspended matter in the water column and estuarine sediments.
- Similarly, suspended matter concentrations of mercury, lead, Total PCB, Total PAH, and Total DDT were consistent with observations of surface sediments, further confirming the link between suspended matter in the water column and estuarine sediments.
- Contaminants that were characteristic of Lower Passaic River sediments were also detected in biota samples, indicating the likelihood of ongoing biological impacts due to contaminants in Lower Passaic River sediments.
- Measurements of 2,3,7,8-TCDD in blue crab revealed the diagnostic ratio of 2,3,7,8-TCDD/TCDD observed in the sediments. The results for dioxins in mummichogs and white perch had ratio values of 1, similar to, but higher than the typical range of the ratio observed in the sediments.

Volume of Contaminated Sediment (Section 5.0)

- Estimations ranged from 2.8 to 8.0 million cubic yards for the volume of contaminated sediment in the Lower Passaic River (*circa* 1995-2005), and the average depth of contamination ranged from 4.6 to 13 feet. These estimates were based on several different approaches with the highest values yielded by the extrapolation of the contaminant inventories (additional deposition since 1995 would be expected to add to this volume) and the lowest values interpolated from geotechnical borings. Additional investigation is required to further narrow the range of the estimate.
- A review of the available coring data for the Lower Passaic River (RM 0.9 to 7.0) revealed that most cores did not establish the actual depth of contamination for several major contaminants, including 2,3,7,8-TCDD, Total DDT, and mercury. For each contaminant examined, no more than one third of the cores penetrated to a depth where contaminant concentrations were considered equal to, or close to, background levels. Only the Total PCB dataset contained a majority of cores (60 percent) that penetrate to background levels.
- In total, 50 to 96 percent of the estimated mass of 2,3,7,8-TCDD, Total DDT, and mercury occurs at coring sites that did not reach background levels at the core bottom, with the percentage varying by contaminant.
- Approximately 25 to 48 percent of the available cores, depending on contaminant, were considered very uncertain with respect to the depth of contamination (*i.e.*, concentration trends that increased with depth.)
- Two inventory estimates were generated for the mass of each of four contaminants in the Lower Passaic River. The first estimate was based on an interpolation of core measurements; the second was based on the extrapolation of the core measurements

where the core did not establish the depth of contamination. The interpolated volume is considered a minimum estimate due to the uncertainties in depth of contamination. The extrapolated inventory represented an increase of 33 to 72 percent over the interpolated estimate, depending on the contaminant (Table 6-1).

Table 6-1: Summary of Contaminant Inventory Estimates

Inventory Estimate [a]	Total DDT (Metric ton) [b]	2,3,7,8-TCDD (kg) [b]	Mercury (Metric ton) [b]	Total PCB (Metric ton) [b]
Interpolated	6.4	20	24	6
Extrapolated	11	29	37	8
Percent Increase [c]	72 percent	45 percent	54 percent	33 percent

a: See text for discussion; Table 6-1 presents the same data as Table 5-7
b: Estimates rounded to two significant figures (when appropriate). 2,3,7,8-TCDD is in units of kilograms
c: Percent increase is relative to the interpolated mass estimate

- Inventories of these four contaminants were shown to correlate, indicating that their inventories coincide in space and are consistent with the anticipated geochemical behavior of the compounds. Essentially, when a location has a locally high inventory of any one of these four contaminants, the other contaminants will also be concentrated at that location. It is anticipated that similar behavior will be exhibited by any hydrophobic compound in the Lower Passaic River.
- Contaminant inventories vary along the length of the Lower Passaic River with maximum values occurring near RM 1 to 2, RM 3 to 4, and RM 6 to 7. However, the coring data indicate a high degree of spatial heterogeneity, suggesting that localized areas of relatively higher concentrations typically described as "hot spots" do not exist. Instead, "hot" regions of the river typically exist on the scale of a mile or more, nearly bank to bank in lateral extent.

In summary, the Lower Passaic River contains a massive volume of contamination, estimated to be at least 2.8 million cubic yards, and more likely, to be in the range of 5 to 8 million cubic yards. Sediment core data record the long history of contamination in this system, yet the existing cores are not sufficient to characterize the entire volume of contamination. In fact, several important contaminants have no known "bottom," indicating that substantially more contamination lies at depth. Contaminant inventories are highest at RM 3 to 4 in the vicinity of the 80 Lister Avenue site. However, the spatial heterogeneity in the data suggests the occurrence of broad areas of contamination, instead of readily definable "hot spots." Contaminant behavior is well predicted by geochemical theory, as demonstrated by coincident inventories of several contaminants. Several important contaminants originate in the Upper Passaic River, above the Dundee Dam, including mercury, lead, and cadmium. Conversely, Total DDT and 2,3,7,8-TCDD clearly originate in the Lower Passaic River. Total PCB loads appear to have changed over time with the Upper Passaic River most important historically but apparently less important relative to Lower Passaic River loads currently. Review of the surface sediment contamination concentrations shows an increased frequency of high outlier values in samples collected between RM 3 and 4.5, indicating that erosion of historic contaminant inventories continue to be a source of contaminants. Finally, the Lower Passaic River remains the major source of 2,3,7,8-TCDD contamination to the sediments

of Newark Bay, representing at least 80 percent of the load. Conversely, the Lower Passaic River is currently a relatively minor contributor of mercury to Newark Bay, whose largest single source (or sources) appears to be unknown.

7.0   ACRONYMS

CARP:	Contaminant Assessment Reduction Program
COPC:	Chemical of Potential Concern
COPEC:	Chemical of Potential Ecological Concern
Cs-137:	Cesium-137
CSO:	Combined Sewage Overflow
DDD:	1,1-dichloro-2,2-bis-(p-chlorophenyl)ethane
DDE:	1,1-dichloro-2,2-bis-(p-chlorophenyl)ethylene
DDT:	1,1,1-trichloro-2,2-bischlorophenylethane
ESRI:	Environmental Systems Research Institute, Inc.
FL:	Fluoranthene
FL/(FL+PY):	Fluoranthene to the sum of fluoranthene plus pyrene ratio
FL/PY:	Fluoranthene to pyrene ratio
g/year:	grams per year
GIS:	Geographic Information System
GMS:	Groundwater Modeling Systems
HMW PAH:	High-Molecular Weight Polycyclic Aromatic Hydrocarbons
MPA:	Mass Per Unit Area
μg/kg:	microgram per kilogram
mg/kg:	milligram per kilogram
N:	Sample size
NA:	Not applicable
NGVD29:	National Geodetic Vertical Datum of 1929
NJDEP:	New Jersey Department of Environmental Protection
NJDOT-OMR:	Office of Maritime Resources/New Jersey Department of Transportation
PAH:	Polycyclic Aromatic Hydrocarbons
PCB:	Polychlorinated Biphenyls
PCDD:	Polychlorinated Dibenzodioxins
pCi/g:	picoCuries per gram
PC1:	First principal components
PY:	Pyrene
RM:	River Mile
SVOC:	Semivolatile Organic Compounds
2,3,7,8-TCDD:	2,3,7,8-Tetrachlorinated-p-dibenzodioxin
TCDD:	Tetrachlorinated dibenzodioxin
TEF:	Toxic Equivalent Factor
TEQ:	Toxic Equivalent Quotient
TIN:	Triangulated Irregular Network
TSI:	Tierra Solutions, Inc.
USACE:	United States Army Corps of Engineers
USEPA:	United States Environmental Protection Agency
UK:	Unknown value
WWTP:	Waste Water Treatment Plant
σ:	Standard Deviation

8.0   REFERENCES

ATSDR, 1995. "Toxicological profile for polycyclic aromatic hydrocarbons." US Department of Health and Human Services. August 1995.

Aqua Survey, Inc., 2005. "Draft Technical Report: Geophysical Survey." Prepared by Aqua Survey, Inc. under contract to EarthTech, Inc., Lower Passaic River Restoration Project. August 2005

Battelle, Inc., 2005a. "Pathway Analysis Report." Prepared by Battelle, Inc. under contract to Malcolm Pirnie, Inc., Lower Passaic River Restoration Project. July 2005

Battelle, Inc., 2005b. "2005-10-31 Battelle Evaluation of Historical Biological Data." Prepared by Battelle, Inc. under contract to Malcolm Pirnie, Inc., Lower Passaic River Restoration Project. October 2005.

Baumard P, Budzinski H, Michon Q, Garrigues P, Burgeot T, and Bellocq J, 1998. "Origin and bioavailability of PAHs in the Mediterranean Sea from mussel and sediment records." Estuarine and Coastal Shelf Science. 47: 77–90.

Bopp RF, Chillrud SN, Shuster EL, and Simpson HJ, 2006. "Contaminant Chronologies from Hudson River Sedimentary Records." In: The Hudson River Estuary, J. Levinton and J. Waldman eds., Cambridge University Press, January 2006, Chapter 26: 383-397.

Bopp RF, Gross ML, Tong H, Simpson HJ, Monson SJ, Deck BL, and Moster FC, 1991a. "A major incident of dioxin contamination: Sediments of New Jersey Estuaries." Environmental Science Technology. 25(5): 951-956.

Bopp RF Gross ML, Tong H, Simpson HJ, Monson SJ, Deck BL, and Moster FC, 1991b. "Sediment sampling and radionuclide and chlorinated hydrocarbon analysis in Newark Bay and the Hackensack and Passaic Rivers." Report to New Jersey Department of Environmental Protection, Division of Science and Research Contract P24096, March 31, 1991.

Bopp RF, Simpson HJ, Olsen, CR, Trier, RM and Kostyk, N, 1982. "Chlorinated hydrocarbons and radionuclide chronologies in sediments of the Hudson River and Estuary, New York." Environmental Science Technology. 16(10): 666-676.

Boul HL, 1994. "DDT residues in the environment - a review with New Zealand perspective." New Zealand Journal of Agricultural Research. 38: 257-277.

Canton L and Grimalt JO, 1992. "Gas chromatographic-mass spectrometric characterization of polycyclic aromatic hydrocarbon mixtures in polluted coastal sediment." Journal of Chromatography. 607: 279-286.

Chaky DA, 2003. "Polychlorinated Biphenyls, Polychlorinated Dibenzo-p-Dioxins and Furans in the New York Metropolitan Area; Interpreting Atmospheric Deposition and Sediment Chronologies." PhD Thesis, Rensselaer Polytechnic Institute, Troy, NY. August 2003.

Costa HJ and Sauer TC, 2005. "Forensic approaches and considerations in identifying PAH background." Environmental Forensics. 6: 9-16.

Gearing JN, Buckley DE, and Smith JN, 1991. "Hydrocarbon and metal contents in a sediment core from Halifax harbor: A chronology of contamination." Canadian Journal of Fish and Aquatic Science. 48: 2344-2354.

Huntley SL, Wenning RJ, Su SH, Bonnevie NL, and Paustenbach DJ, 1991. "Geochronology and sedimentology of the Lower Passaic River, New Jersey." Estuaries. 18(2): 351-361.

HydroQual, Inc., 2005a. "Draft Modeling Work Plan." Prepared by HydroQual, Inc. under contract to Malcolm Pirnie, Inc., Lower Passaic River Restoration Project. April 2005.

HydroQual, Inc., 2005b. "2005-12-08 HydroQual Evaluation of Historical Water Column Data." Prepared by HydroQual, Inc. under contract to Malcolm Pirnie, Inc., Lower Passaic River Restoration Project. December 2005.

Konsevick E, 1991. "Sediment Geochemistry of the Hackensack Meadowlands." Hackensack River Symposium V, Fairleigh Dickinson University.

Lima ALC, Eglinton TI, and Reddy CM, 2003. "High resolution record of pyrogenic polycyclic aromatic hydrocarbon deposition during the 20th century." Environmental Science and Technology. 37 (1), 53–61.

Lowe S, Abood K, Ko J, and Wakeman T, (in press). "A sediment budget analysis of Newark Bay." Journal of Marine Science and Environment.

Ma H, Jones KW, and Stern EA, 1998. "Scientific visualization and data modeling of scattered sediment contaminant data in New York/New Jersey estuaries." Proceedings of the Conference on Visualization (Research Triangle Park, North Carolina): pp. 467-470.

MacGregor JS, 1974. "Changes in the amount and proportions of DDT and its metabolites, DDE and DDD, in the marine environment off Southern California, 1949-72." Fishery Bulletin. 72(2), 275-293.

Malcolm Pirnie, Inc., 2005. "Preliminary Geochemical Evaluation." Appendix B in: Lower Passaic River Restoration Project Work Plan. Prepared in conjunction with Battelle, Inc. and HydroQual, Inc. August 2005.

Metcalf RL, 1995. "Insect Control Technology" In: Kirk-Othmer Encyclopedia of Chemical Technology. Kroschwitz J, Howe-Grant M, eds. Volume 14. New York, NY: John Wiley and Sons, Inc., 524-602.

NJDEP, 2002. "Chapter 8: Impact of mercury on New Jersey's ecosystems." In: Mercury Task Force. Online report published by NJDEP (http://www.state.nj.us/dep/dsr/mercury_task_force.htm; last visited on February 6, 2006)

NJDEP, 1998. "Guidance for Sediment Quality Evaluations." New Jersey Department of Environmental Protection (Treton, NJ).

NJDOT-OMR, 2000. "Restoration of the Passaic River Conceptual Proposal." Office of Maritime Resources New Jersey Department of Transportation. Revised: March 17, 2000.

Olsen CR, Simpson HJ, Peng TH, Bopp RF, and Trier RM, 1981. "Sediment mixing and accumulation rate effects on radionuclide depth profiles in Hudson Estuary sediments." J. Geophysical Research. 86(C11): 11020-11028.

Olsen CR, 1979. "Radionuclides, sedimentation and the accumulation of pollutants in the Hudson Estuary." Ph.D Thesis. Columbia University, New York. 234 pp.

Sanders PF, 2003. "Ambient levels of metals in New Jersey Soils." Division of Science, Research, and Technology. New Jersey Department of Environmental Protection.

Soclo HH, Garrigues PH, and Ewald M, 2000. "Origin of polycyclic aromatic hydrocarbons (PAHs) in coastal marine sediments: Case studies in Cotonou (Benin) and Aquitaine (France) areas." Marine Pollution Bulletin. 40 (5), 387–396.

Suszkowski DJ, 1978. "Sedimentology of Newark Bay, New Jersey: An urban estuarine bay." PhD Thesis, University of Delaware.

Tierra Solutions, Inc., 1995a "Passaic River Study Area: Field Sampling Plan." Volume 3 of 5, January 1995.

Tierra Solutions, Inc., 1995b "Passaic River Study Area: Quality Assurance Project Plan." Volume 3 of 5, January 1995.

USEPA, 1998. "Guidance for Data Quality Assessment." QA/G-9, QA97 Version. Office of Research and Development. EPA/600/R-96/084.

USEPA, 1993. "Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons." Office of Research and Development. EPA/600/R-93/089.

USEPA, 1986. "Guidelines for Carcinogen Risk Assessment." Risk Assessment Forum. EPA/630/R-00/004.

Van den Berg *et al.*, 1998. "Toxic Equivalency Factors (TEFs) for PCBs, PCDDs, PCDFs for Humans and for Wildlife." Environmental Health Perspectives. 106: 775.

Van Metre PC, Mahler BJ, and Furlong ET, 2000. "Urban sprawl leaves its PAH signature." Environmental Science and Technology. 34 (19), 4064–4070.

Weis JS and Weis P, 2000. "Benthic Communities and Metal Contaminations in Eight-Day Swamp: A brackish Marsh in the Hackensack Meadowlands of New Jersey." (http://cimic.rutgers.edu/ecorisk/).

Weis P and Weis JS, 2003. "Eight Day Swamp: Assessment of Heavy Metal Contamination and Benthic Biodiversity." Final Report to the Meadowlands Environmental Research Institute.

Yan B, Benedict LA, Chaky DA, Bopp RF, and Abrajano TA, 2004. "Levels and patterns of PAH distribution in sediments of the New York/New Jersey Harbor Complex." Northeastern Geology & Environmental Sciences. 26: 113-122.

Figures
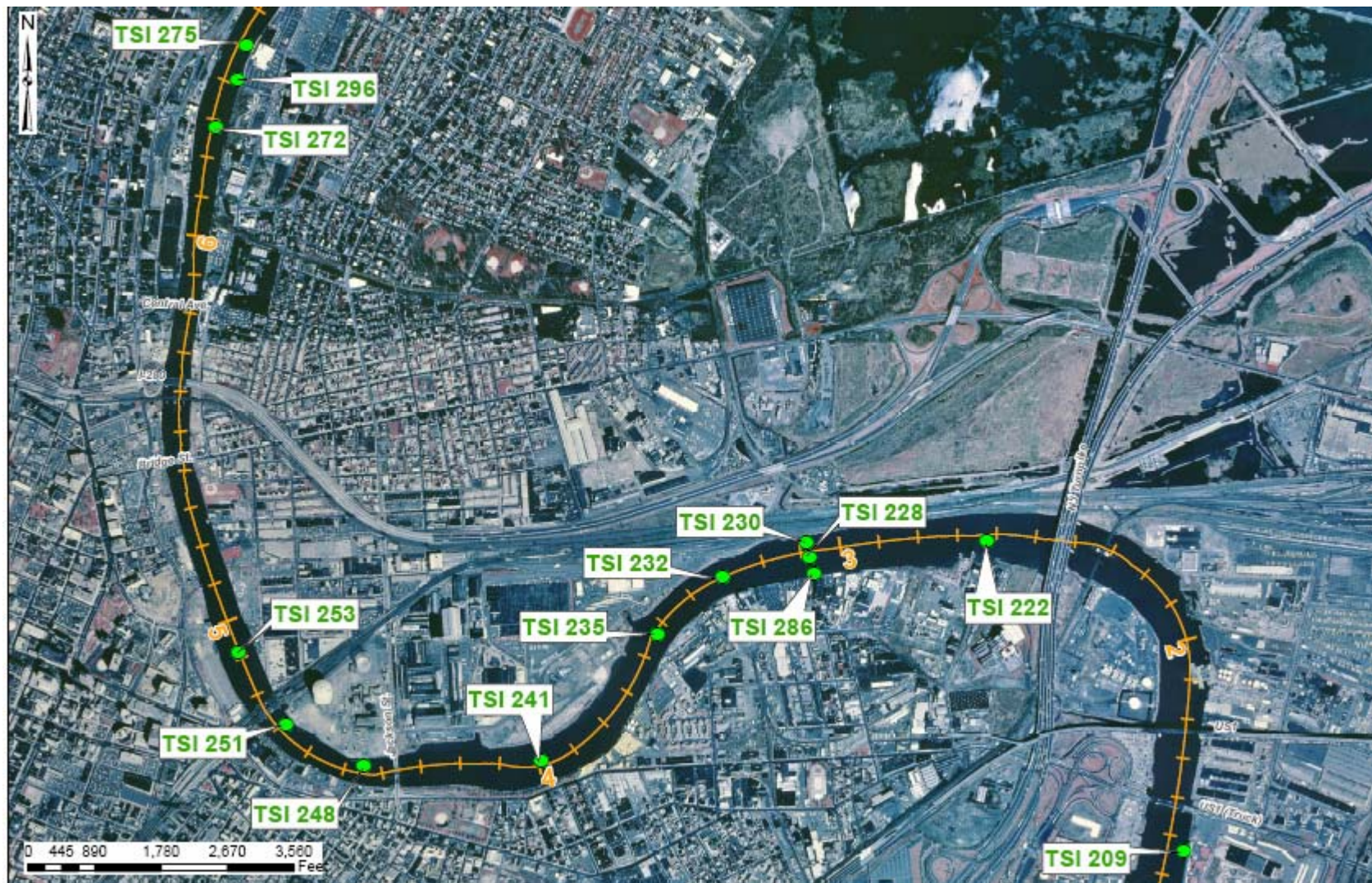
1995 TierraSolutions, Inc. Sampling Locations
(LOCATIONS OF COMPLETE Cs- 137 PROFILES)

Lower Passaic River Restoration Project

Figure 2-1

February 2006
Draft
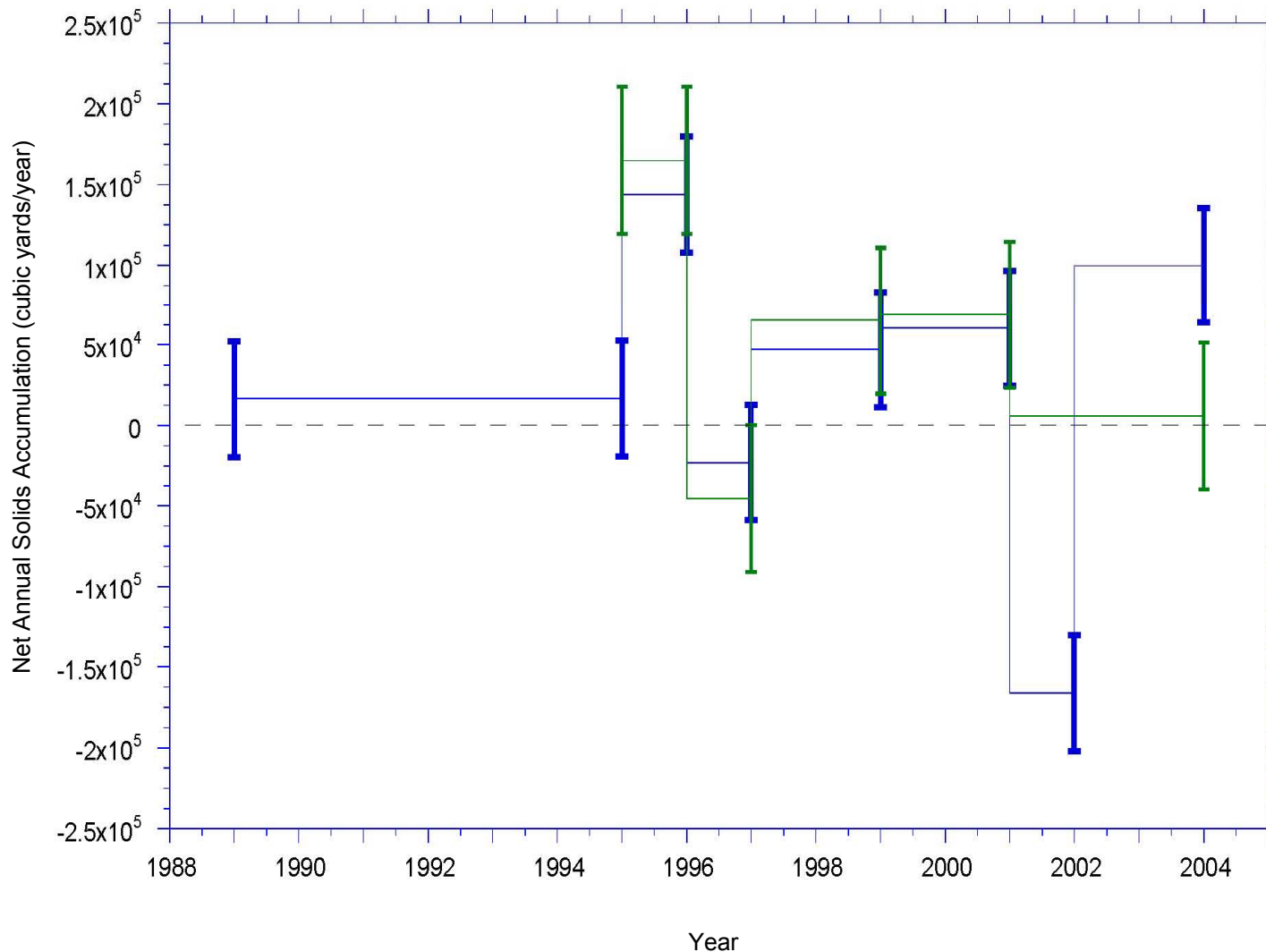
Net Annual Solids Accumulation Rate Based on Bathymetric Survey Evaluation

Lower Passaic River Restoration Project

Figure 3-1

February 2006
Draft

Average Sedimentation Rate by Quarter River Mile

Figure 3-2

February 2006
Draft

Lower Passaic River Restoration Project

N

Point Locations:
The average sedimentation rate (units of inches/year) equals the average of two cesium-137 calculations (whenever possible). Some isotope data were not used in the sedimentation rate calculations because of discontinuities in the cores.

• Plotted a downcore profile of cesium-137 concentration (pCi/g) versus depth, where "depth" equals the average of the top segment depth and the bottom segment depth. Nondetectable cesium concentrations were set to zero.

• Calculated two sedimentation rates: one at the 1963 time horizon (cesium-137 peak concentration) and one at the 1954 time horizon (base of the cesium-137 peak). Note that some cores only showed one time horizon; other cores showed neither time horizon.

Surface:
The sedimentation rate (units of inches/year) depicted as a surface was calculated based on the change in bathymetry from 1995 to 2001. The change of depth was divided by the 6-year period. Bathymetric survey data were from the 1995 TSI Survey and the 2001 TSI Survey. Sounding depths from both the 1995 and 2001 Surveys were converted from USACE Mean Low Water (MLW) to NGVD29 using a factor of 2.4 feet downstream of River Mile 6.8 and 2.3 feet upstream of River Mile 6.8.

A Triangulated Irregular Network (TIN) was derived from the survey points for each dataset using ESRI's 3-D Analyst in ArcGIS. Contours were interpolated from the TIN, also in 3-D Analyst. Each surface was converted to a raster with a 5-foot grid cell size. The change in depth was calculated by subtracting the 1995 raster surface from the 2001 raster surface.

HUDSON

ESSEX

Data Source
(1) The shoreline represented in this map is based on the shoretype dataset available from the New Jersey Department of Environmental Protection and shows a general depiction of the river boundary. The shoreline was further delineated by stereoscopic interpretation of aerial orthophotography. The aerial images used are a snapshot image of the New Jersey coastline and may not be high tide conditions. Some areas that may be submerged during high tide may have appeared as dry land.

(2) The sample locations shown on this map were from the Tierra Solutions Inc. 1995 dataset. Coordinates for each point were provided with the original study data, and these data points were uploaded to the PREmis database.

(3) Transect locations are based on the 2001 bathymetric transects. The 1995 transects align with the 2001 transects, with minor variations.

This (map/publication/report) was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been verified by NJDEP and is not state-authorized.

Legend

Average Sedimentation Rate
(inches / year)

Scour	
0	
0 - 1	
1 - 2	
2 - 3	
3 - 4	
4 - 5	
> 5	

• Core location with no data

□ One sedimentation rate calculation

△ Average of two sedimentation rate calculations

········· Bathymetric Transect Locations

0 375 750 1,500
Feet

CESIUM-137 AND BATHYMETRY-BASED SEDIMENTATION RATES
River Mile 1 to River Mile 7

Lower Passaic River Restoration Project

FIGURE 3-3

FEBRUARY 2006
DRAFT

Comparison of Average Sedimentation Rates

Lower Passaic River Restoration Project

Figure 3-4

February 2006
Draft
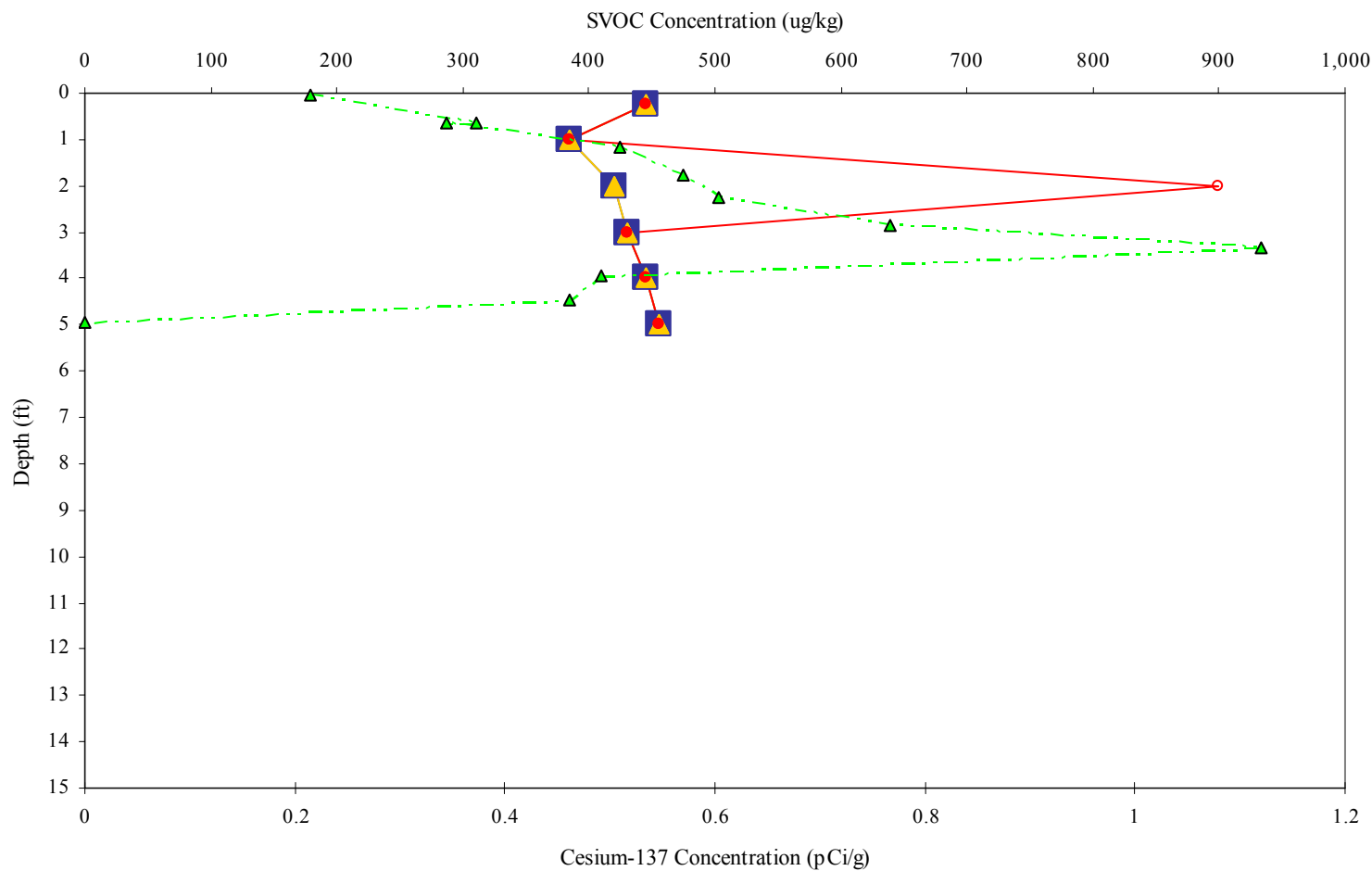
SVOC Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Semivolatile Organic Compounds
(River Mile 1.5)
Lower Passaic River Restoration Project

Figure 4-1a

February 2006
Draft
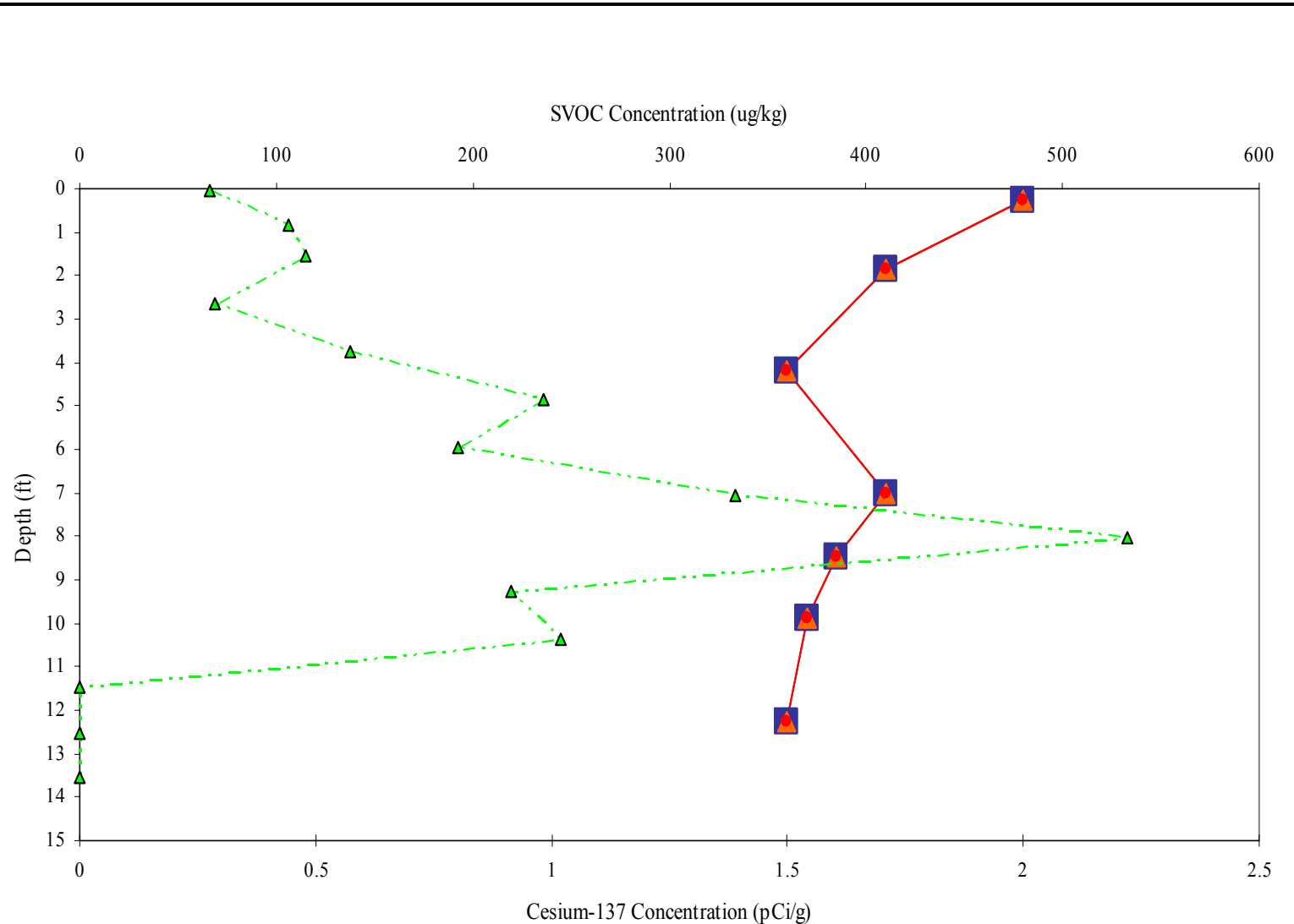
Downcore Profile for Semivolatile Organic Compounds
(River Mile 2.7)
Lower Passaic River Restoration Project

Figure 4-1b

February 2006
Draft
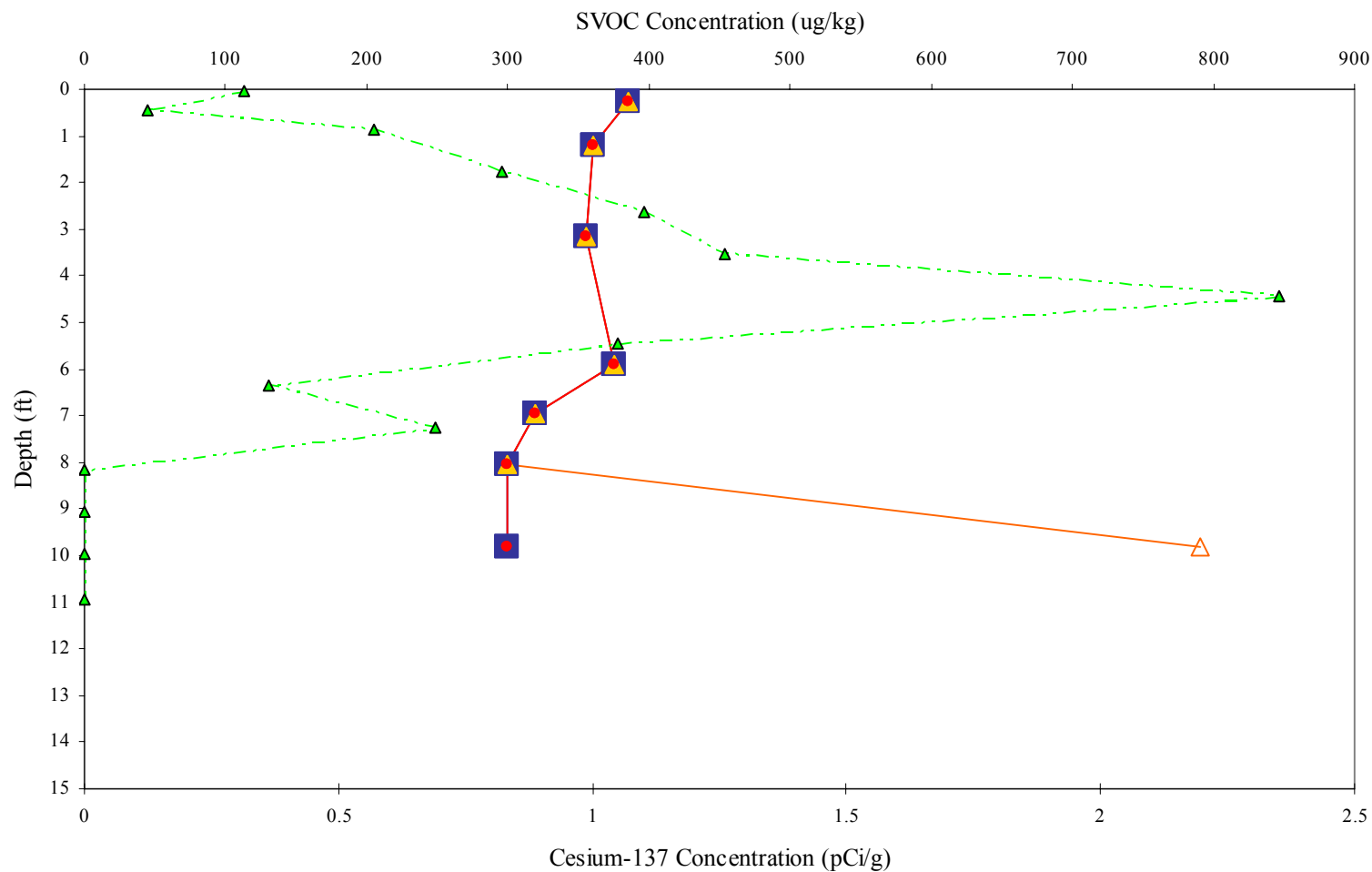
Figure 4-1c

Downcore Profile for Semivolatile Organic Compounds
(River Mile 3.1)

Lower Passaic River Restoration Project

February 2006
Draft

Legend

- 1,4-Dichlorobenzene Detect
- 1,4-Dichlorobenzene Nondetect
- Dibenzofuran Detect
- Dibenzofuran Nondetect
- Butyl benzyl phthalate Detect
- Butyl benzyl phatalate Nondetect
- Cesium-137

Location

May 1995, River Mile 3.1
TSI Location 228

Notes

Only detection is
Dibenzofuran at 800 µg/kg
at 10 ft.

SVOC Concentration (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Downcore Profile for Semivolatile Organic Compounds
(River Mile 3.1)
Lower Passaic River Restoration Project

Figure 4-1d

February 2006
Draft
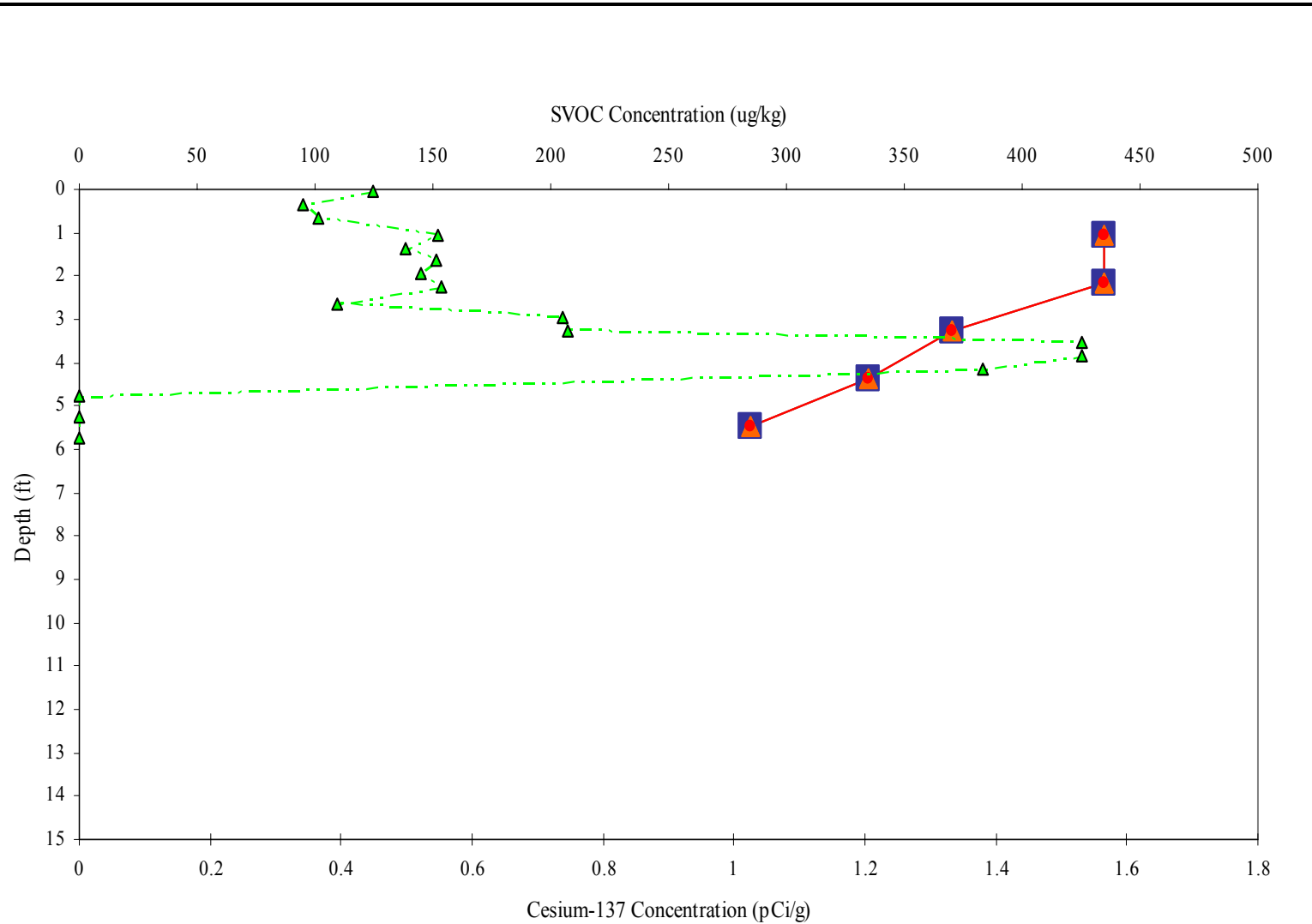
US Army Corps
of Engineers

MALCOLM
PIRNIE

SVOC Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Location

May 1995, River Mile 3.3
TSI Location 232

Notes

No SVOCs detected

Downcore Profile for Semivolatile Organic Compounds
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-1e

February 2006
Draft
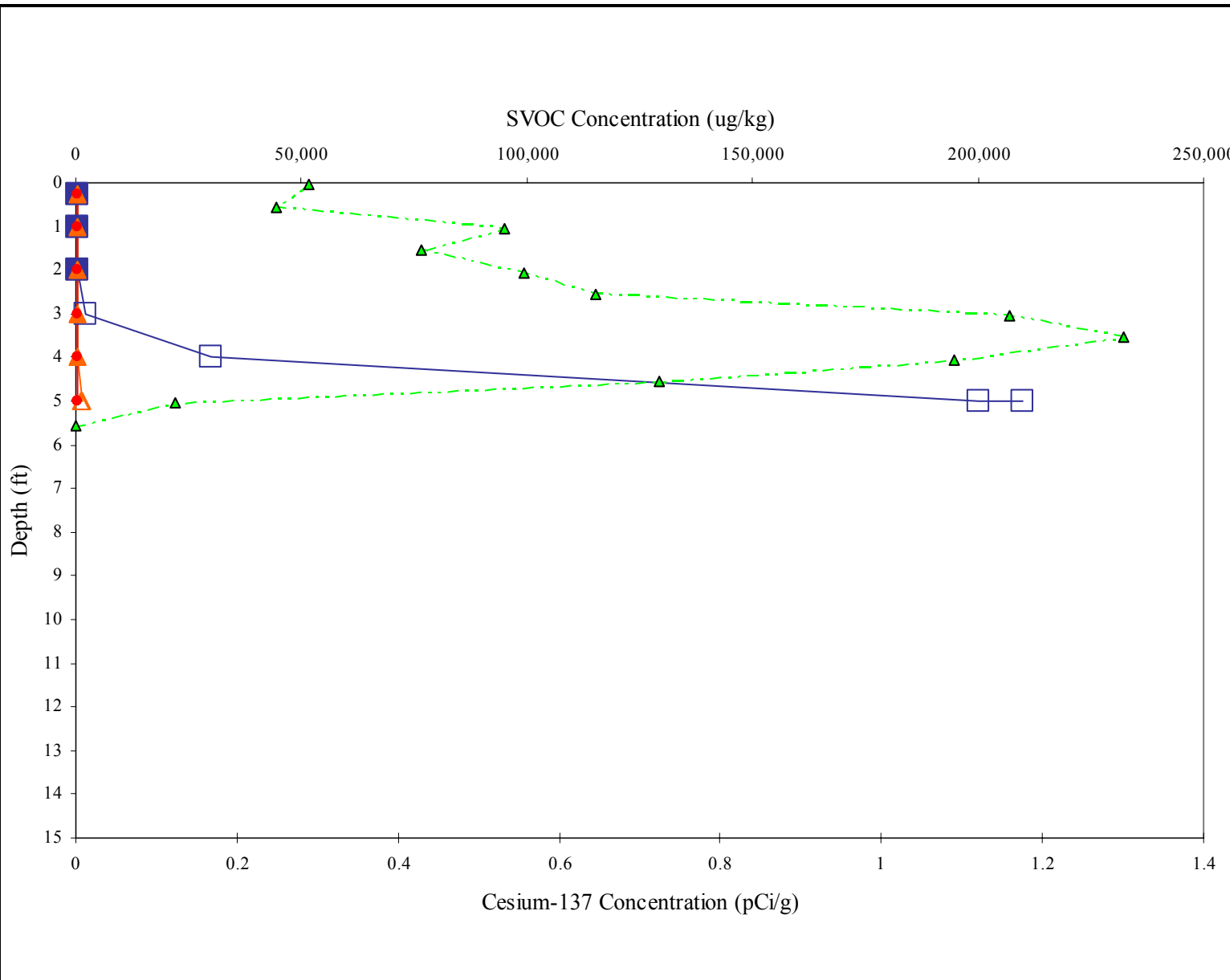
MALCOLM
PIRNIE

Downcore Profile for Semivolatile Organic Compounds
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-1f

February 2006
Draft

SVOC Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Semivolatile Organic Compounds
(River Mile 3.6)
Lower Passaic River Restoration Project

Figure 4-1g

February 2006
Draft
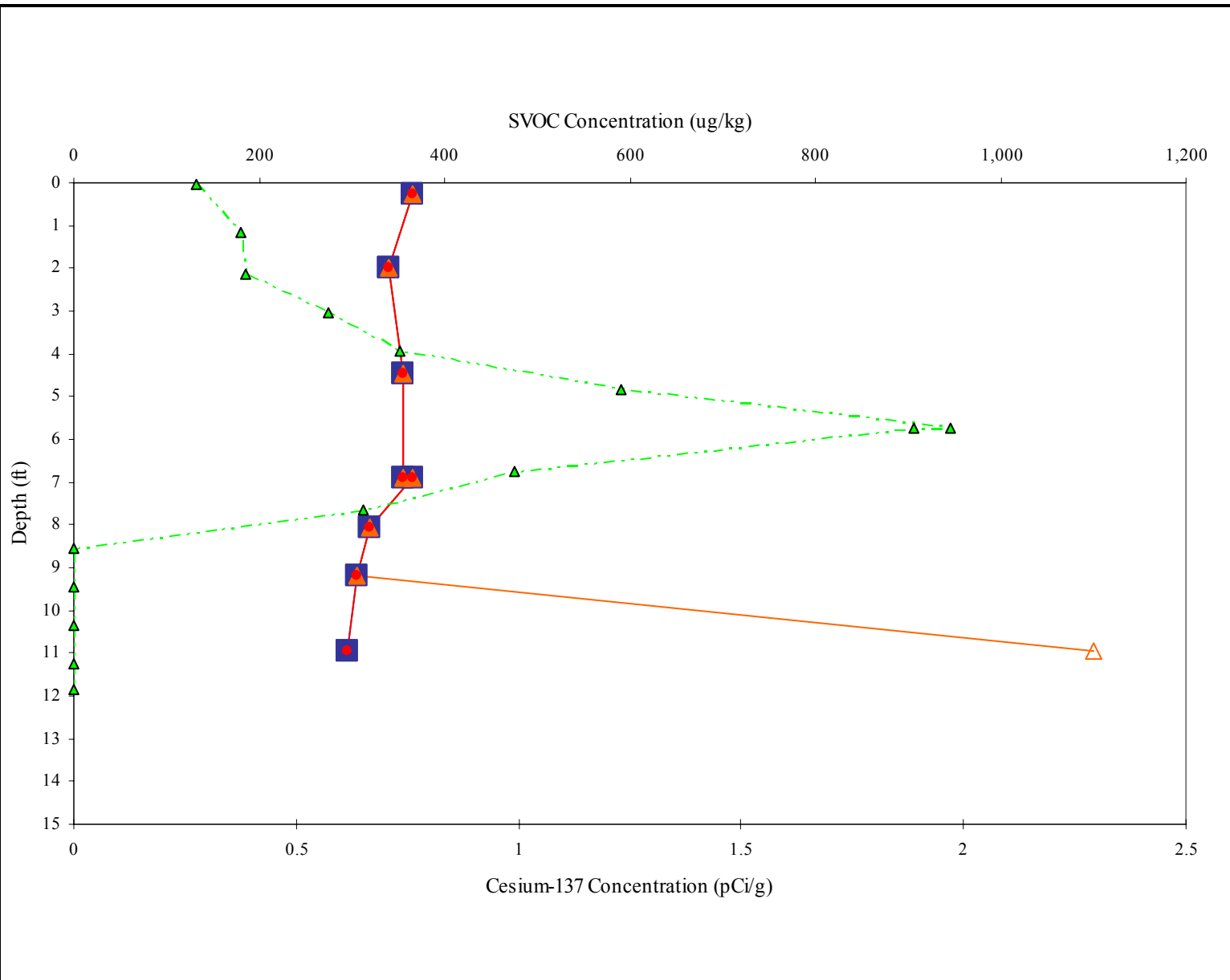
Downcore Profile for Semivolatile Organic Compounds
(River Mile 4.0)
Lower Passaic River Restoration Project

Figure 4-1h

February 2006
Draft
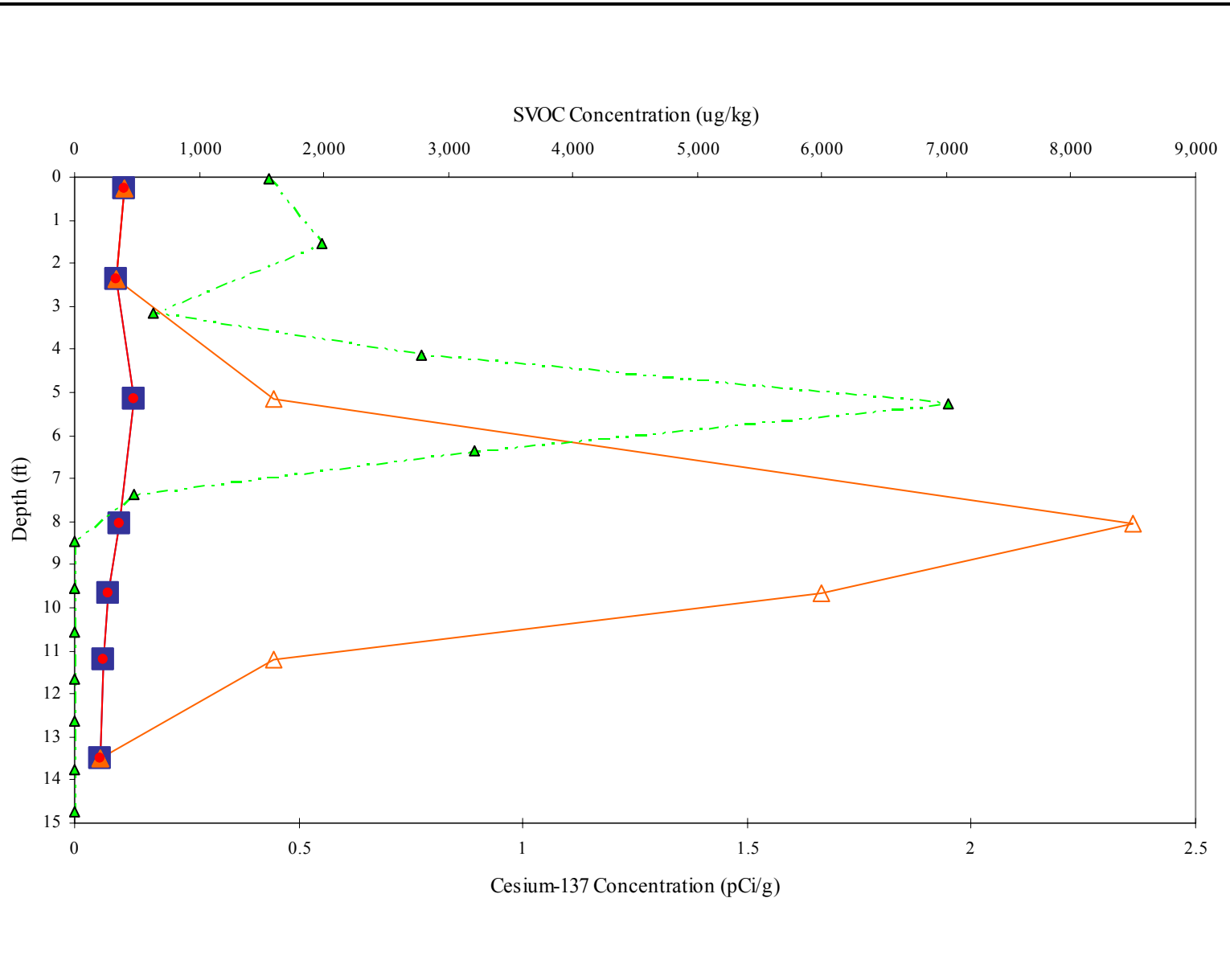
Downcore Profile for Semivolatile Organic Compounds
(River Mile 4.5)

Lower Passaic River Restoration Project

Figure 4-1i

February 2006
Draft
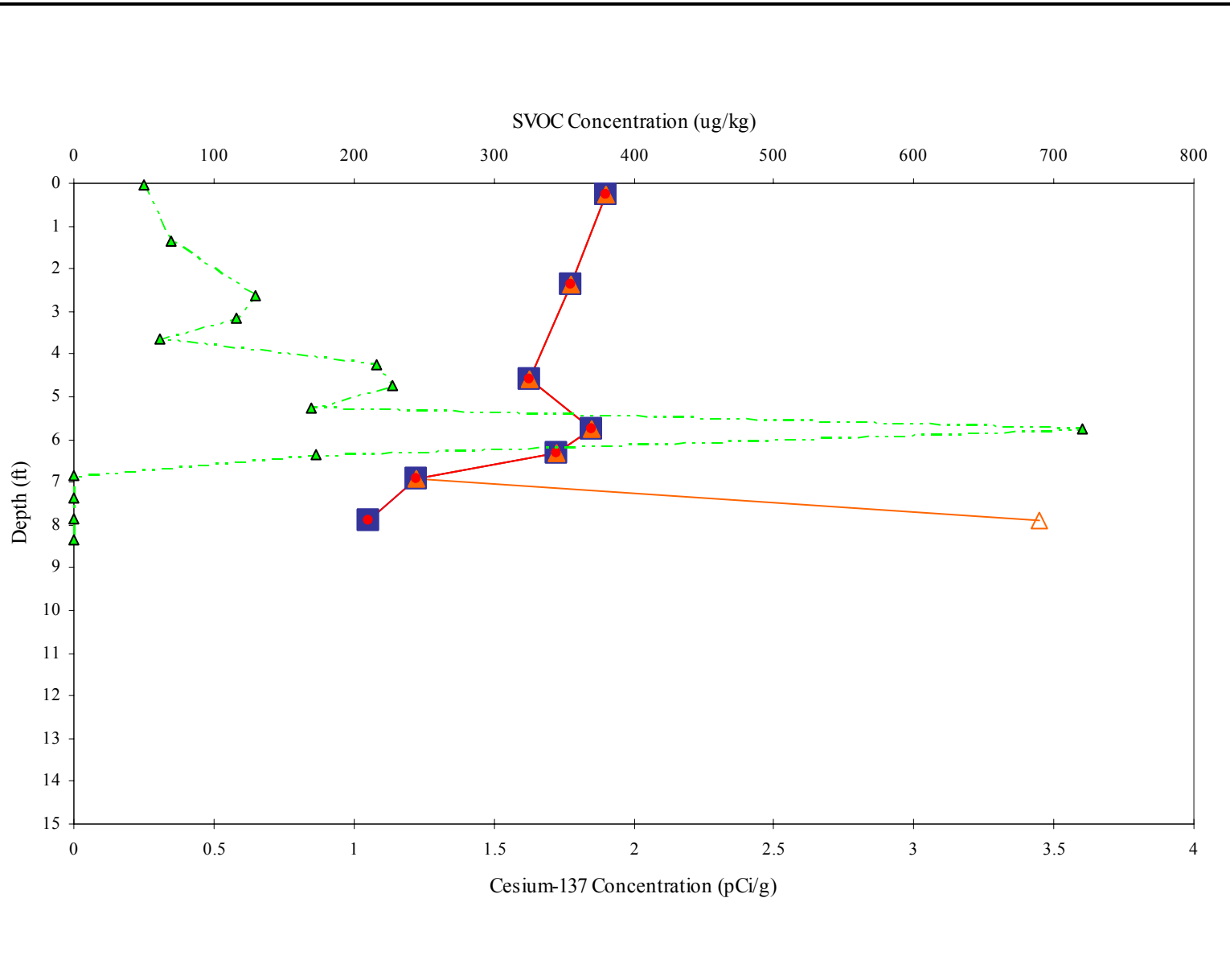
Downcore Profile for Semivolatile Organic Compounds
(River Mile 4.7)

Lower Passaic River Restoration Project

Figure 4-1j

February 2006
Draft

Legend

- 1,4-Dichlorobenzene Detect
- 1,4-Dichlorobenzene Nondetect
- Dibenzofuran Detect
- Dibenzofuran Nondetect
- Butyl benzyl phthalate Detect
- Butyl benzyl phatalate Nondetect
- Cesium-137

Location

May 1995, River Mile 4.7
TSI Location 251

Notes

Only detected SVOC is
dibenzofuran
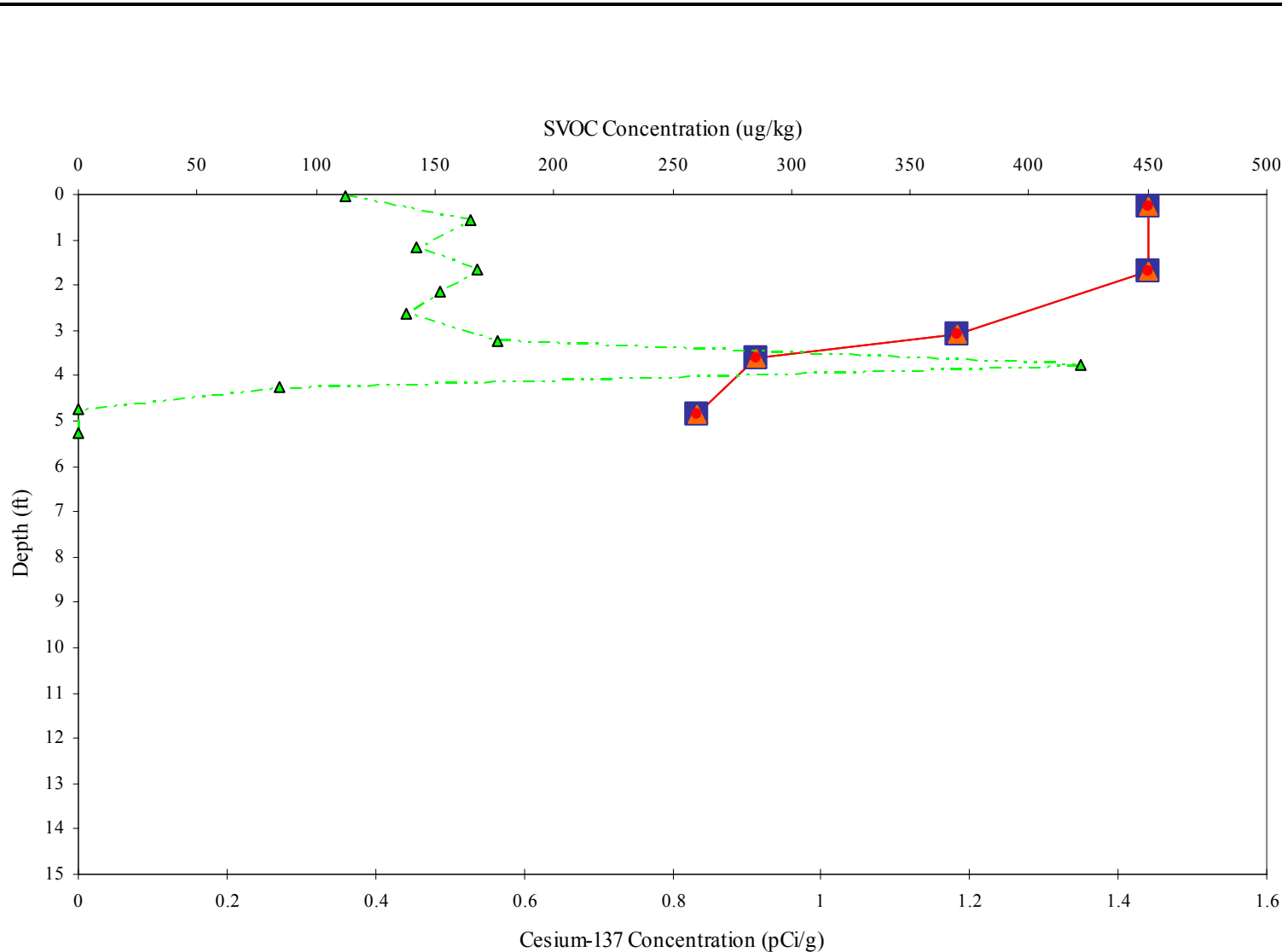
SVOC Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Legend

- 1,4-Dichlorobenzene Detect
- 1,4-Dichlorobenzene Nondetect
- Dibenzofuran Detect
- Dibenzofuran Nondetect
- Butyl benzyl phthalate Detect
- Butyl benzyl phatalate Nondetect
- Cesium-137

Location

May 1995, River Mile 4.9
TSI Location 253

Notes

No SVOCs detected

Downcore Profile for Semivolatile Organic Compounds
(River Mile 4.9)
Lower Passaic River Restoration Project

Figure 4-1k

February 2006
Draft
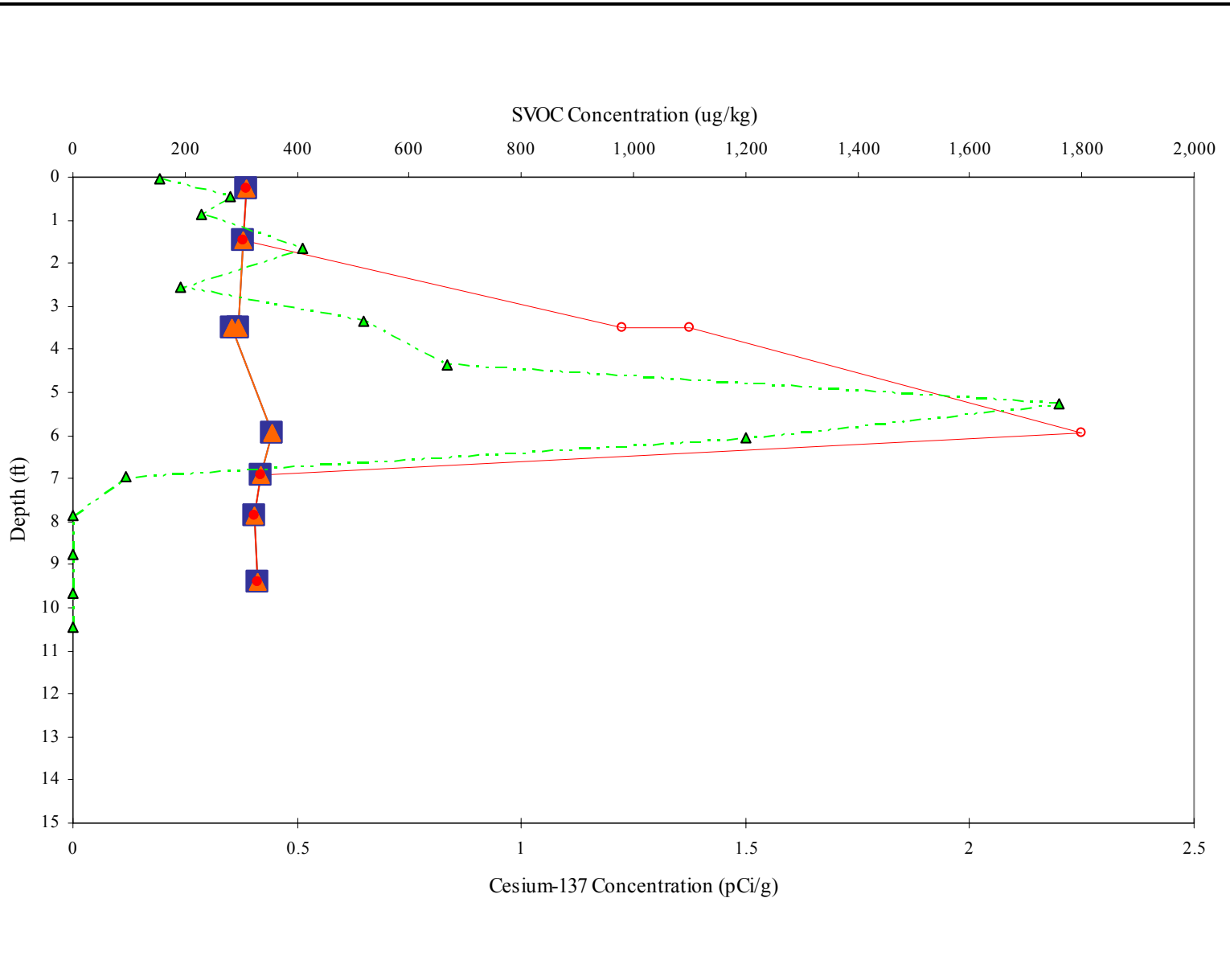
MALCOLM PIRNIE

SVOC Concentration (ug/kg)

Legend

- 1,4-Dichlorobenzene Detect
- 1,4-Dichlorobenzene Nondetect
- Dibenzofuran Detect
- Dibenzofuran Nondetect
- Butyl benzyl phthalate Detect
- Butyl benzyl phatalate Nondetect
- Cesium-137

Location

May 1995, River Mile 6.3
TSI Location 272

Notes

Only SVOC detected is
Butyl benzyl phthalate

Cesium-137 Concentration (pCi/g)

Downcore Profile for Semivolatile Organic Compounds
(River Mile 6.3)
Lower Passaic River Restoration Project

Figure 4-1l

February 2006
Draft
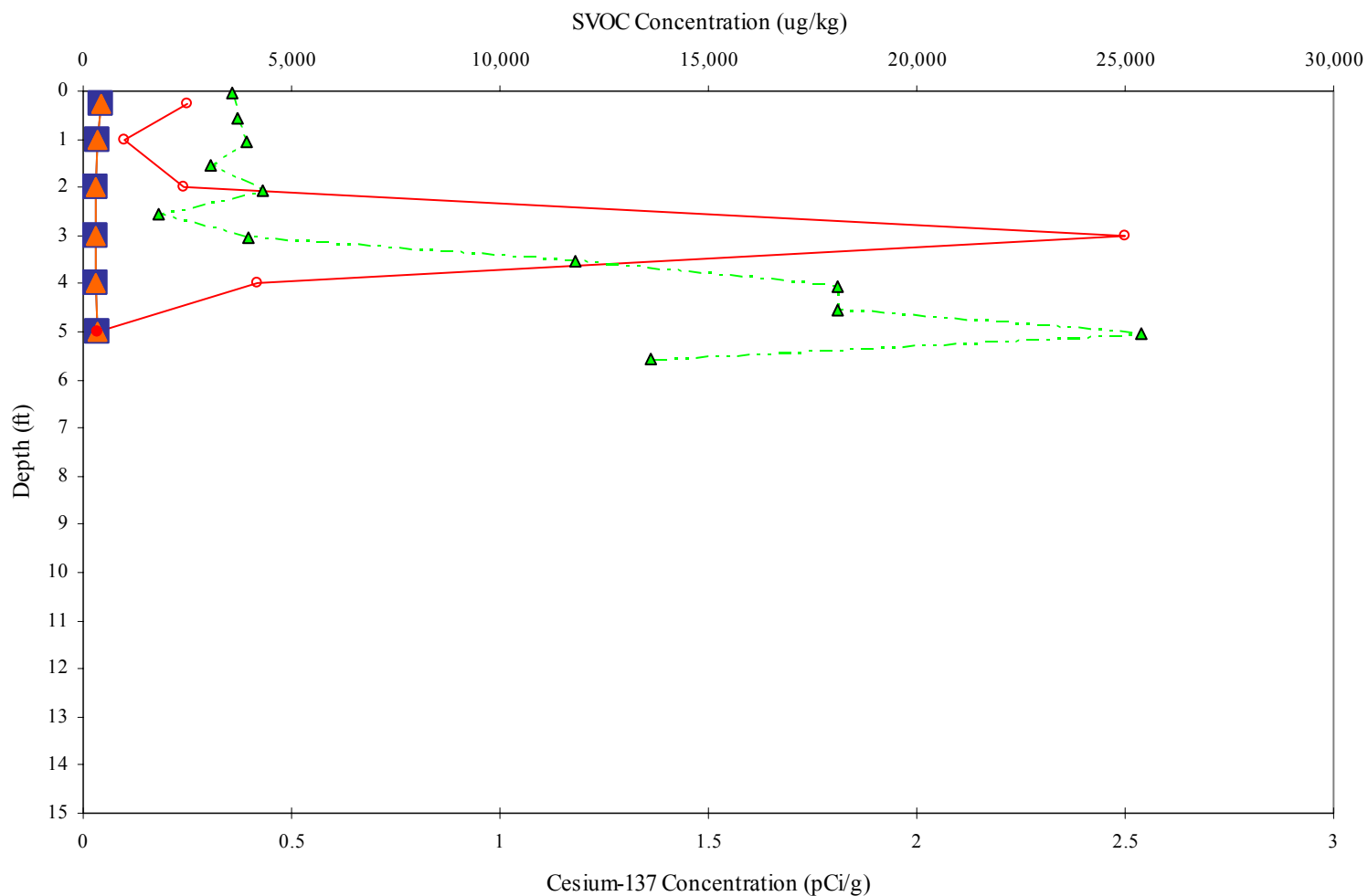
Legend

- □ 1,4-Dichlorobenzene Detect
- ■ 1,4-Dichlorobenzene Nondetect
- △ Dibenzofuran Detect
- ▲ Dibenzofuran Nondetect
- ○ Butyl benzyl phthalate Detect
- ● Butyl benzyl phatalate Nondetect
- ▲ Cesium-137

Location

June 1995, River Mile 6.4
TSI Location 296

Notes

Only SVOC detected is
Butyl benzyl phtalate

Downcore Profile for Semivolatile Organic Compounds
(River Mile 6.4)
Lower Passaic River Restoration Project

Figure 4-1m

February 2006
Draft
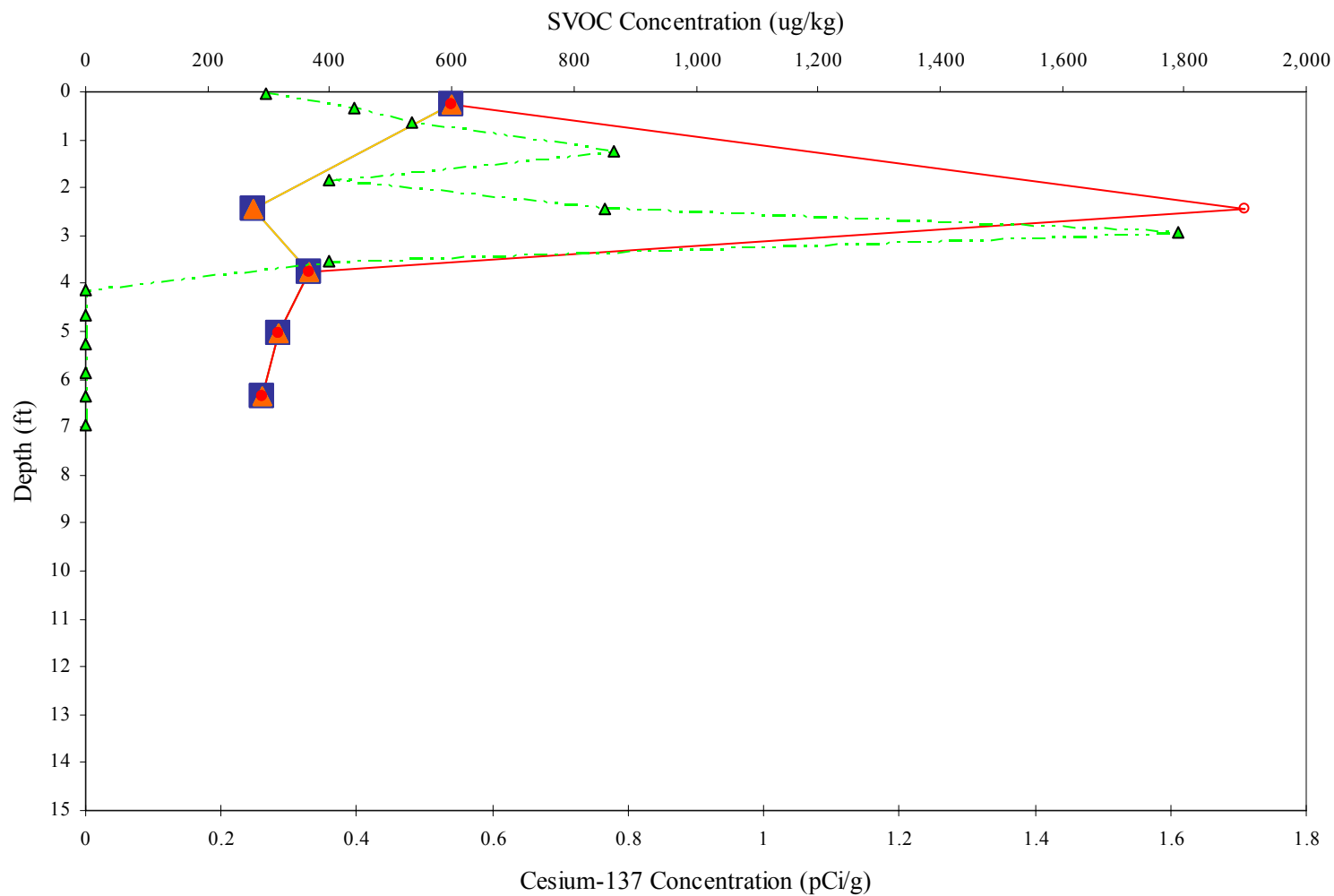
SVOC Concentration (ug/kg)

Legend

- □ 1,4-Dichlorobenzene Detect
- ■ 1,4-Dichlorobenzene Nondetect
- △ Dibenzofuran Detect
- ▲ Dibenzofuran Nondetect
- ○ Butyl benzyl phthalate Detect
- ● Butyl benzyl phatalate Nondetect
- ▲ Cesium-137

Location

June 1995, River Mile 6.5
TSI Location 275

Notes

Only SVOC detection is Butyl benzyl phthalate at 1900 μg/kg at depth of 2.45 ft.

Depth (ft)

Cesium-137 Concentration (pCi/g)

Downcore Profile for Semivolatile Organic Compounds
(River Mile 6.5)
Lower Passaic River Restoration Project

Figure 4-1n

February 2006
Draft

US Army Corps of Engineers®

MALCOLM PIRNIE

PAH Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Total PAH and HMW PAH
(River Mile 1.5)

Lower Passaic River Restoration Project

Figure 4-2a

February 2006
Draft

MALCOLM
PIRNIE

Figure 4-2b

Downcore Profile for Total PAH and HMW PAH
(River Mile 2.7)

Lower Passaic River Restoration Project

February 2006
Draft

Legend

Total PAH
HMW PAH
Cesium-137

Notes

1. Total PAH represents the sum of the 16 Priority PAH Pollutants. If one or more of the PAHs were not analyzed, then Total PAH is not plotted. Non-detected values (lab qual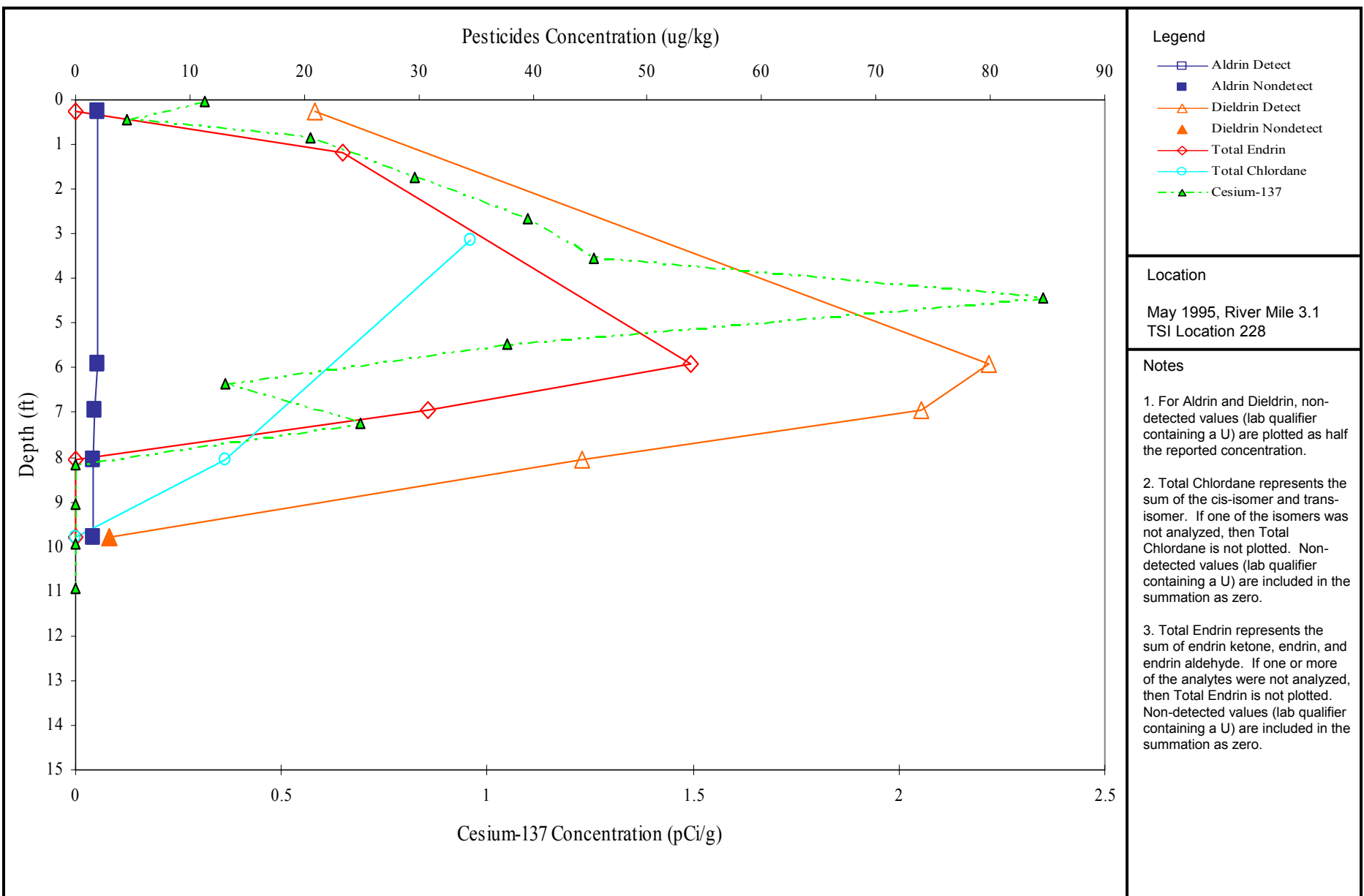ifier containing a U) are included in the summation as zero. Note that 2-methylnapthalene, benzo(e)pyrene, and perylene are not included in the summation because they are not a priority pollutant.

2. High Molecular Weight (HMW) PAH represents the sum of the 10 HMW PAH from the Priority PAH Pollutants list. If one or more of the PAHs were not analyzed, then HMW PAH is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.
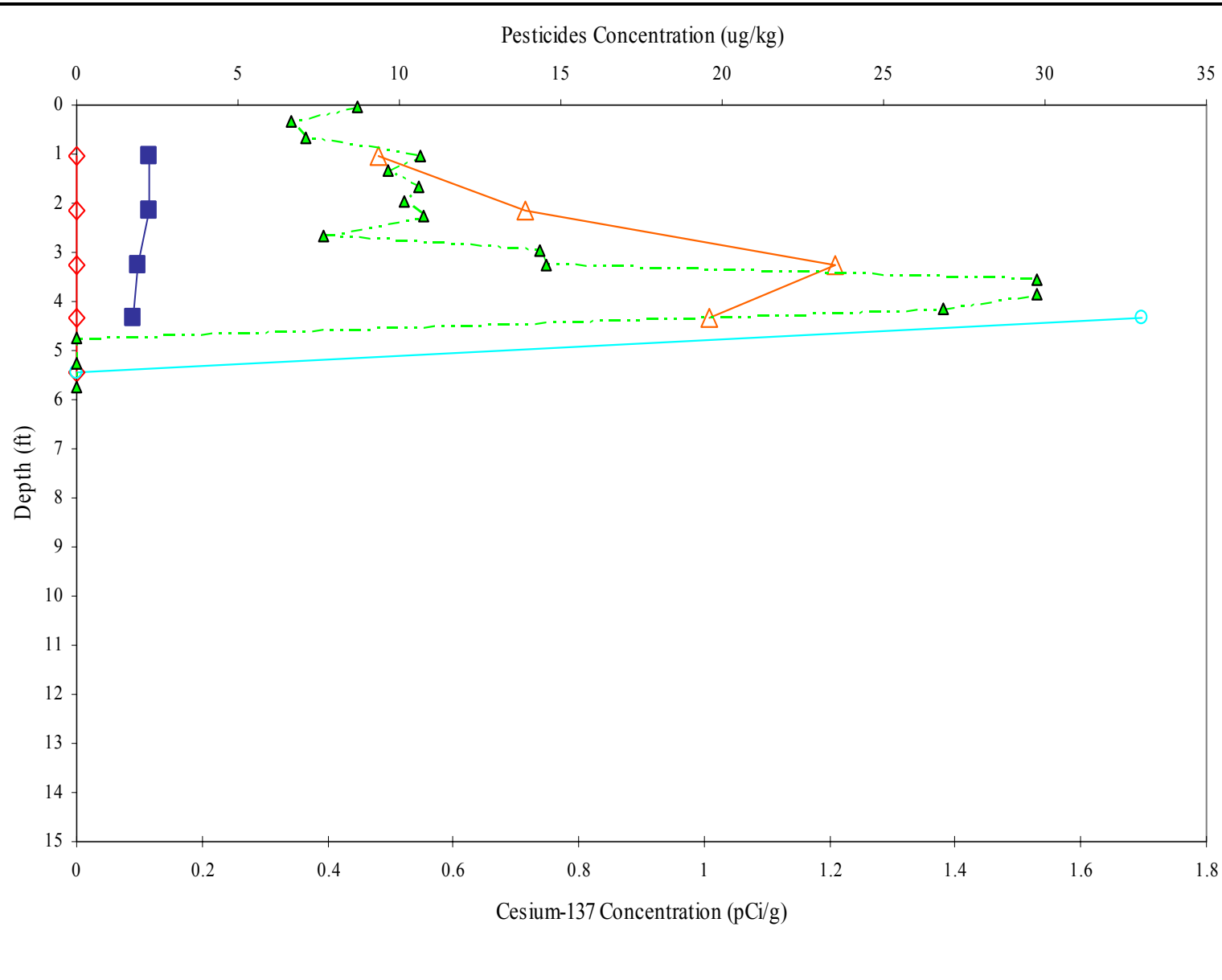
3. Total PAH background concentrations were taken from ATSDR for urban soils. Available online:

http://www.atsdr.cdc.gov/toxprofiles/tp69-c5.pdf.

4. High background includes samples from Passaic Watershed.

PAH Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Total PAH and HMW PAH
(River Mile 3.1)

Lower Passaic River Restoration Project

Figure 4-2c

February 2006
Draft

MALCOLM
PIRNIE

PAH Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Total PAH and HMW PAH
(River Mile 3.1)
Lower Passaic River Restoration Project

Figure 4-2d

February 2006
Draft

MALCOLM
PIRNIE

PAH Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)
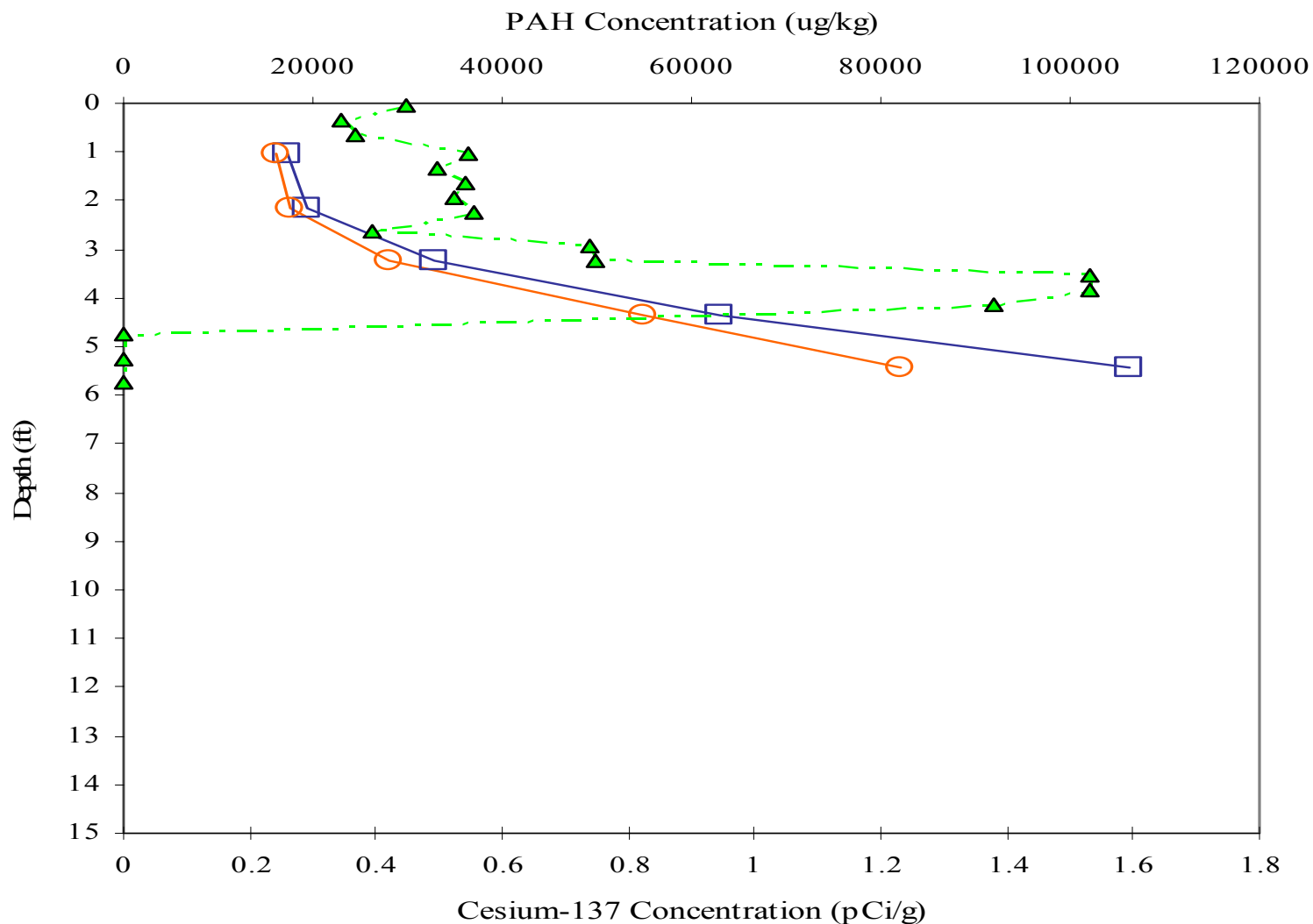
Location

May 1995, River Mile 3.3
TSI Location 232

Notes

1. Total PAH represents the sum of the 16 Priority PAH Pollutants. If one or more of the PAHs were not analyzed, then Total PAH is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero. Note that 2-methylnapthalene, benzo(e)pyrene, and perylene are not included in the summation because they are not a priority pollutant.

2. High Molecular Weight (HMW) PAH represents the sum of the 10 HMW PAH from the Priority PAH Pollutants list. If one or more of the PAHs were not analyzed, then HMW PAH is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

3. Total PAH background concentrations were taken from ATSDR for urban soils. Available online:

http://www.atsdr.cdc.gov/toxprofiles/tp69-c5.pdf.

4. High background includes samples from Passaic Watershed.

Downcore Profile for Total PAH and HMW PAH
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-2e

February 2006
Draft
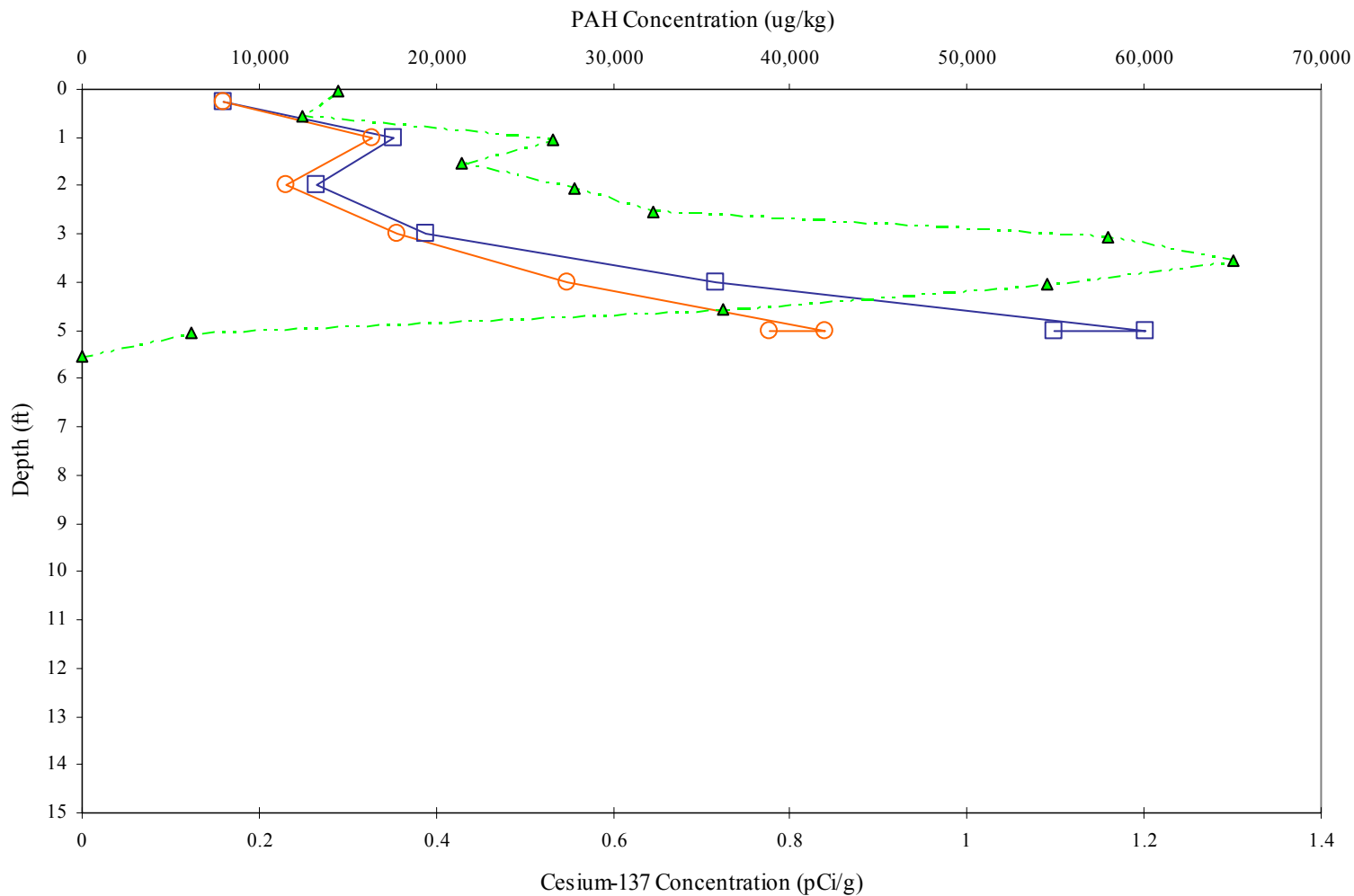
PAH Concentration (ug/kg)

Location

June 1995, River Mile 3.3
TSI Location 286

Notes

1. Total PAH represents the sum of the 16 Priority PAH Pollutants. If one or more of the PAHs were not analyzed, then Total PAH is not plotted. Non-detected values (lab qual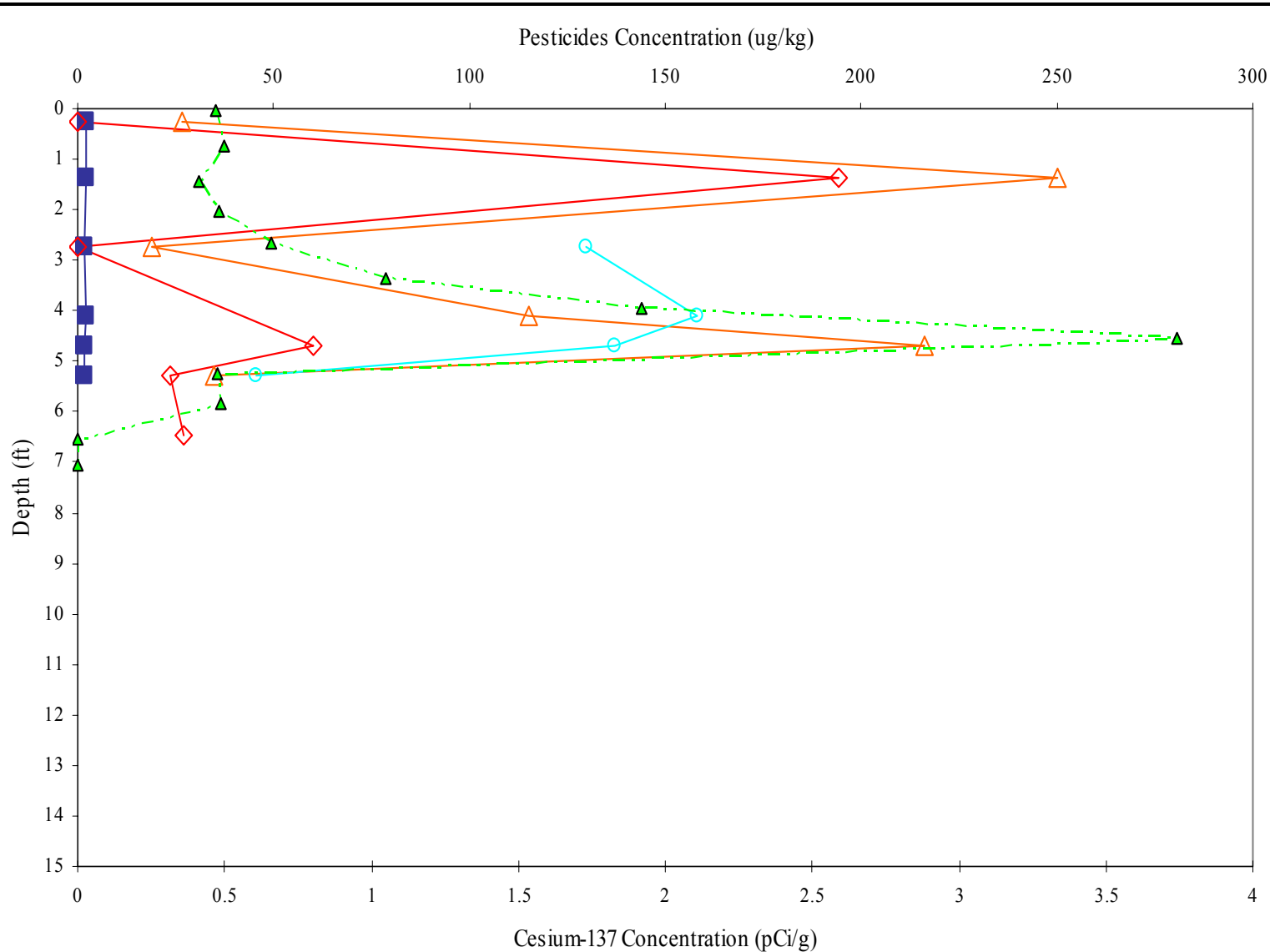ifier containing a U) are included in the summation as zero. Note that 2-methylnapthalene, benzo(e)pyrene, and perylene are not included in the summation because they are not a priority pollutant.

2. High Molecular Weight (HMW) PAH represents the sum of the 10 HMW PAH from the Priority PAH Pollutants list. If one or more of the PAHs were not analyzed, then HMW PAH is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.
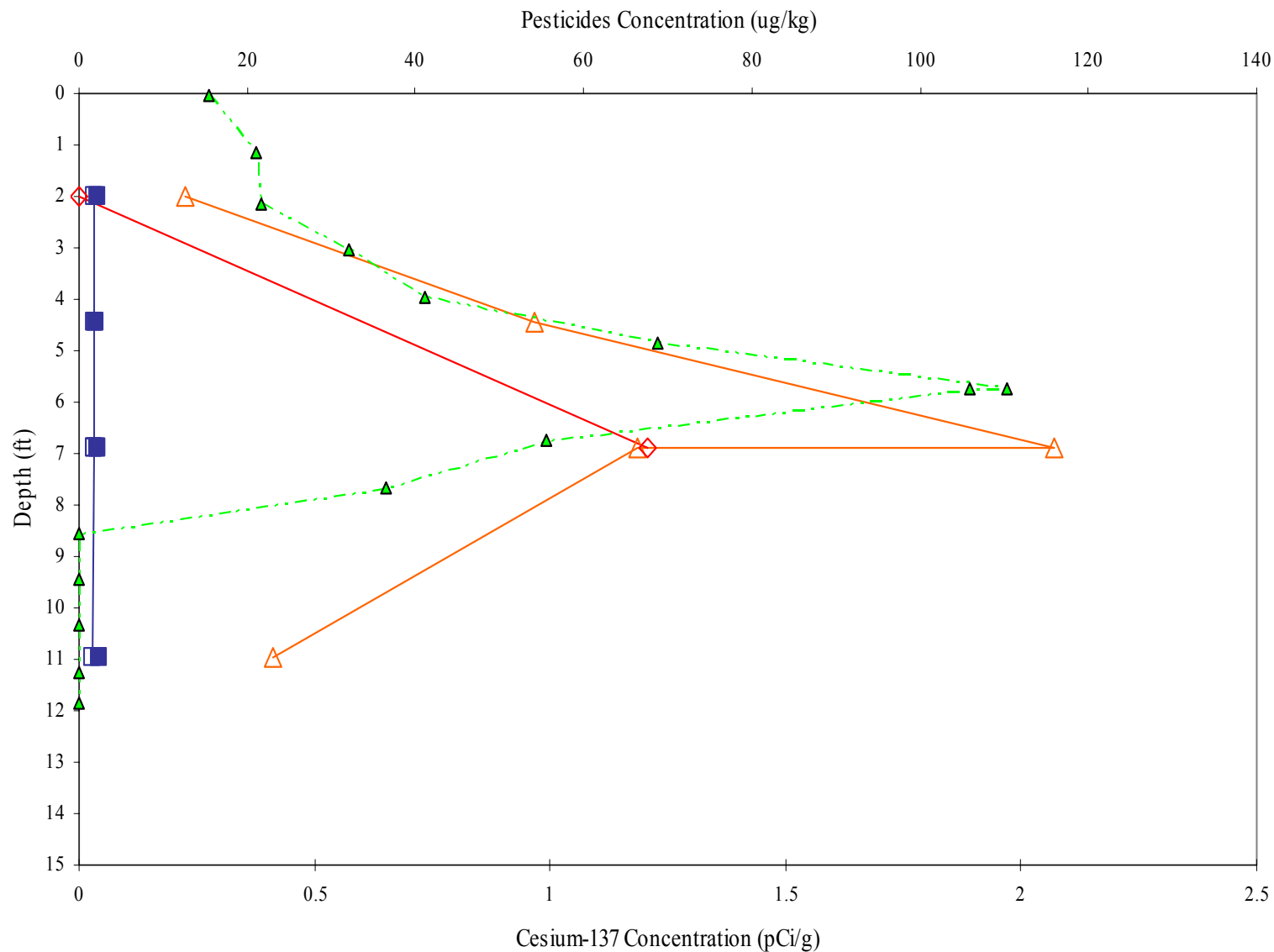
3. Total PAH background concentrations were taken from ATSDR for urban soils. Available online:

http://www.atsdr.cdc.gov/toxprofiles/tp69-c5.pdf.

4. High background includes samples from Passaic Watershed.

Cesium-137 Concentration (pCi/g)

Downcore Profile for Total PAH and HMW PAH
(River Mile 3.3)

Lower Passaic River Restoration Project

Figure 4-2f

February 2006
Draft

PAH Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Total PAH and HMW PAH (River Mile 3.6)

Lower Passaic River Restoration Project

Figure 4-2g

February 2006
Draft

MALCOLM PIRNIE

US Army Corps of Engineers

Downcore Profile for Total PAH and HMW PAH
(River Mile 4.0)

Lower Passaic River Restoration Project

Figure 4-2h

February 2006
Draft

PAH Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Total PAH and HMW PAH
River Mile 4.5)

Lower Passaic River Restoration Project

Figure 4-2i

February 2006
Draft

Downcore Profile for Total PAH and HMW PAH (River Mile 4.7)

Lower Passaic River Restoration Project

Figure 4-2j

February 2006
Draft

PAH Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)
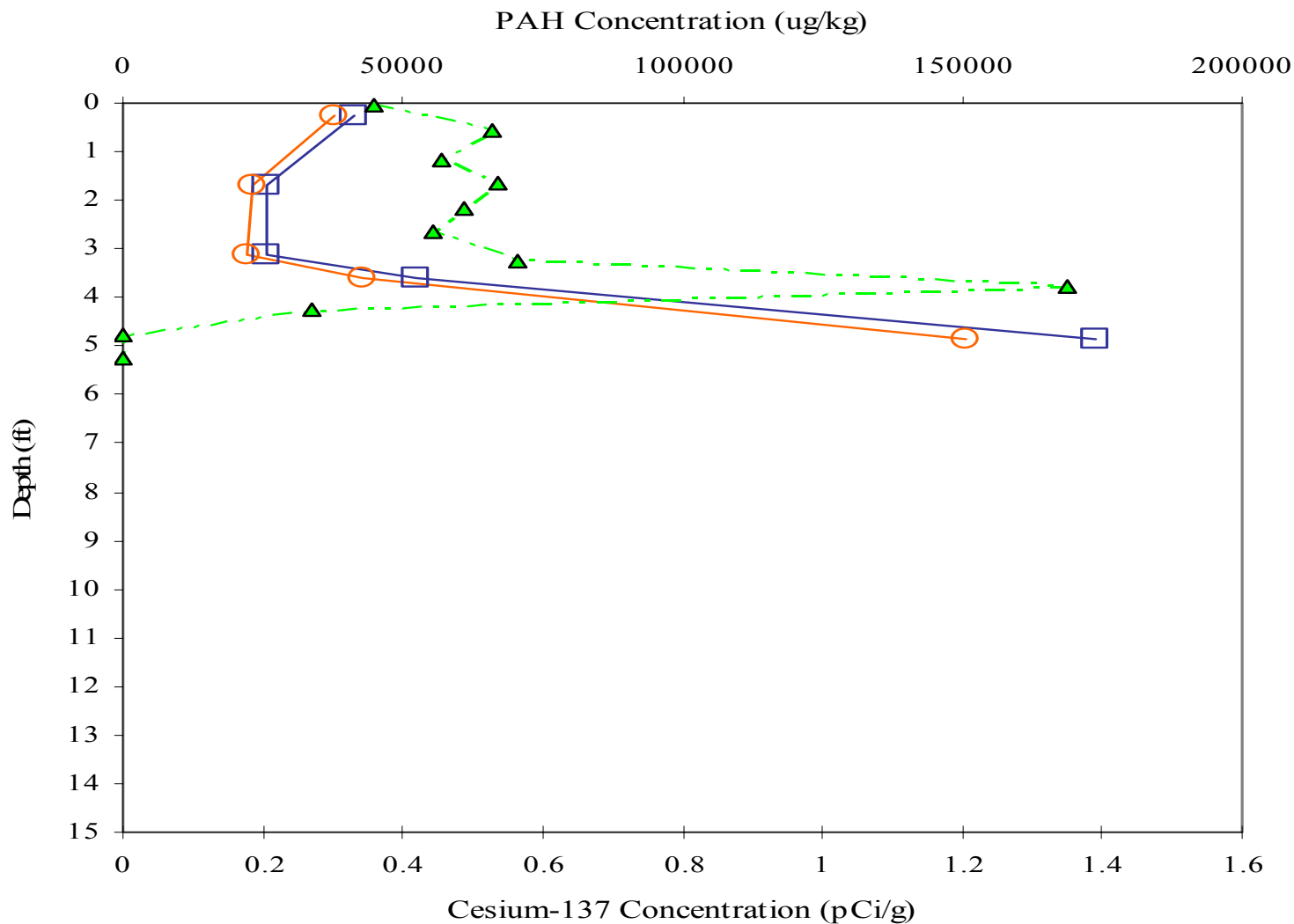
Location

May 1995, River Mile 4.9
TSI Location 253

Notes

1. Total PAH represents the sum of the 16 Priority PAH Pollutants. If one or more of the PAHs were not analyzed, then Total PAH is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero. Note t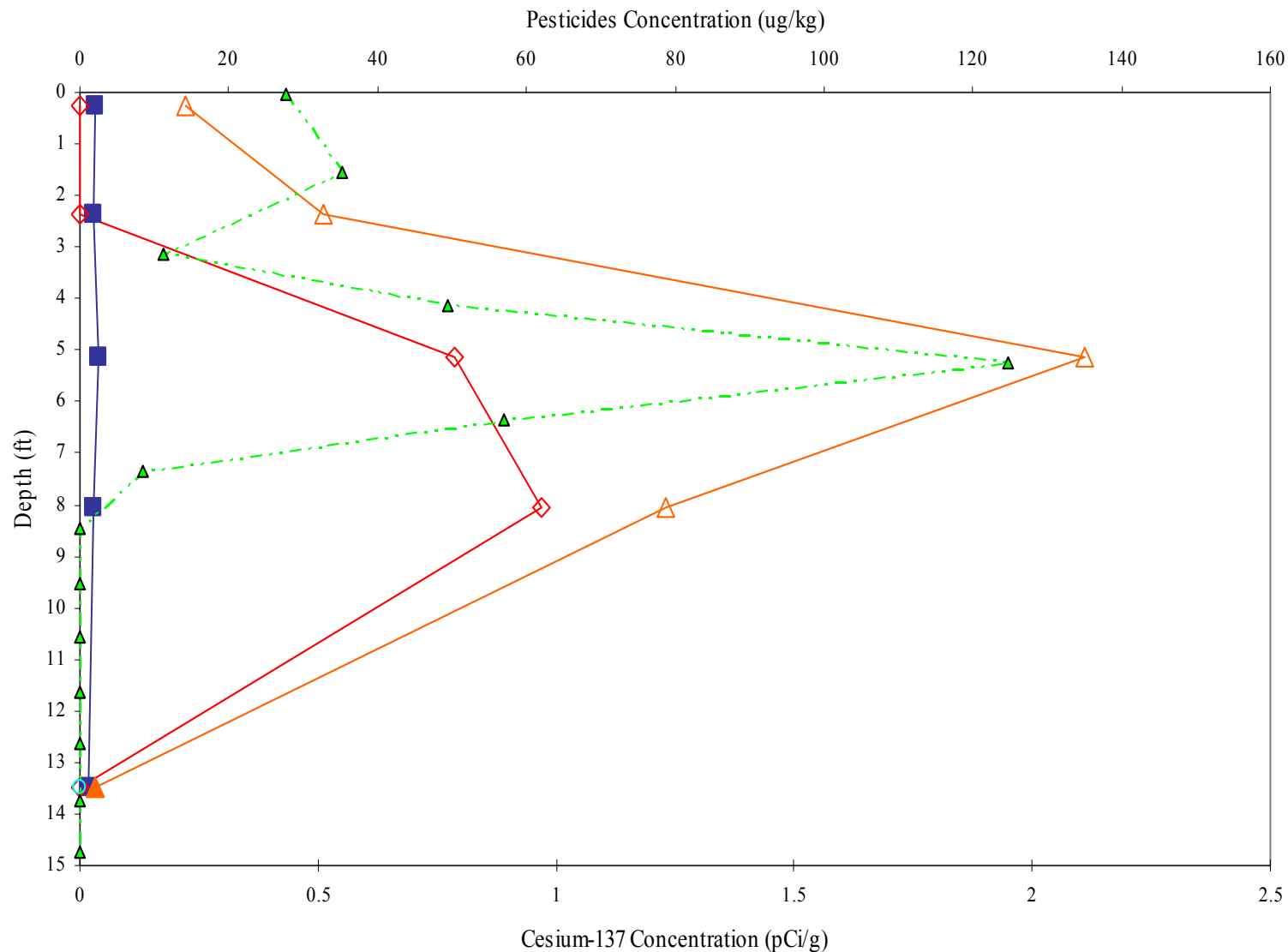hat 2-methylnapthalene, benzo(e)pyrene, and perylene are not included in the summation because they are not a priority pollutant.

2. High Molecular Weight (HMW) PAH represents the sum of the 10 HMW PAH from the Priority PAH Pollutants list. If one or more of the PAHs were not analyzed, then HMW PAH is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

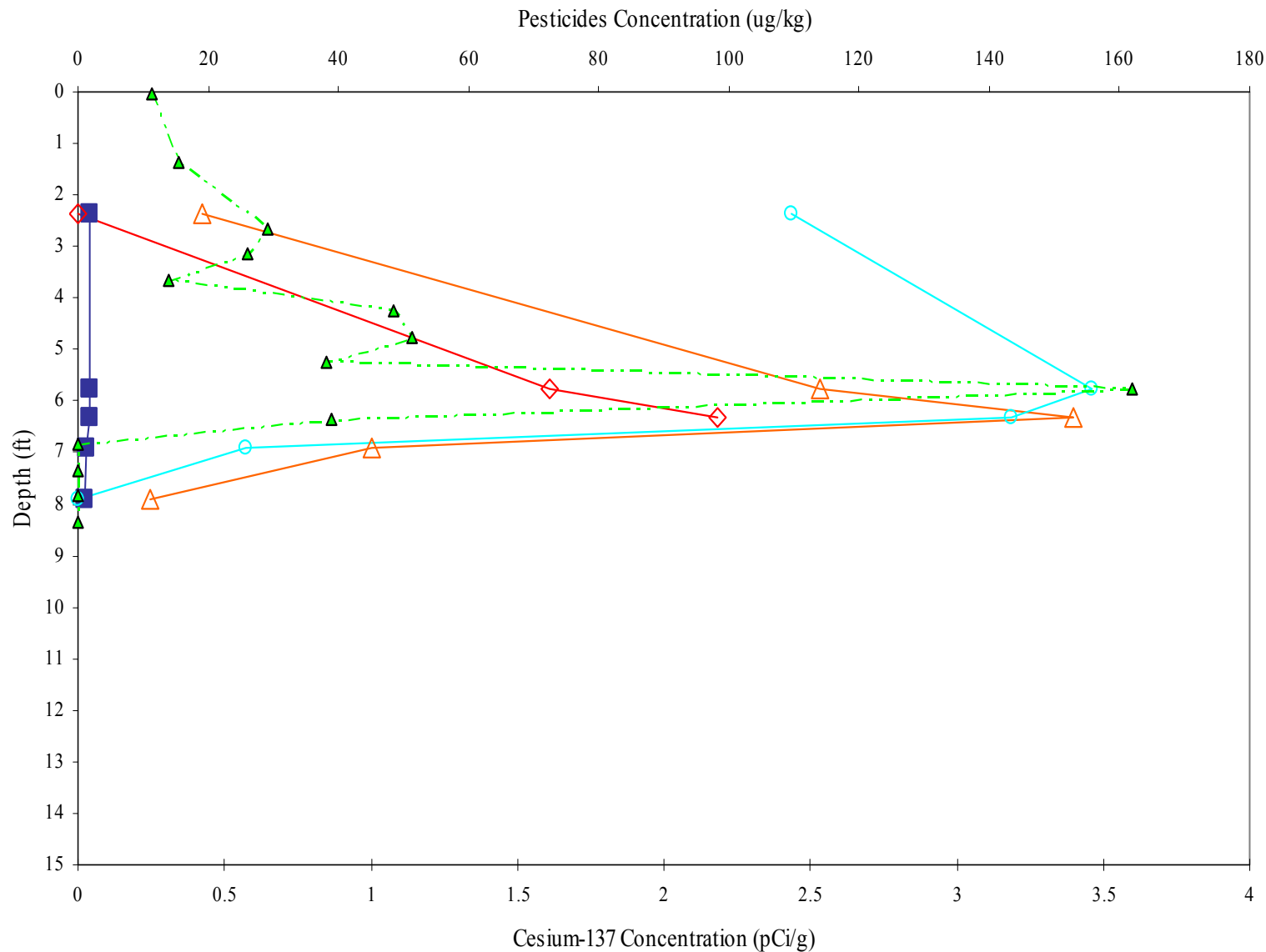3. Total PAH background concentrations were taken from ATSDR for urban soils. Available online:

http://www.atsdr.cdc.gov/toxprofiles/tp69-c5.pdf.

4. High background includes samples from Passaic Watershed.

Downcore Profile for Total PAH and HMW PAH
(River Mile 4.9)

Lower Passaic River Restoration Project

Figure 4-2k

February 2006
Draft

MALCOLM PIRNIE

Downcore Profile for Total PAH and HMW PAH
(River Mile 6.3)

Lower Passaic River Restoration Project

Figure 4-2l

February 2006
Draft
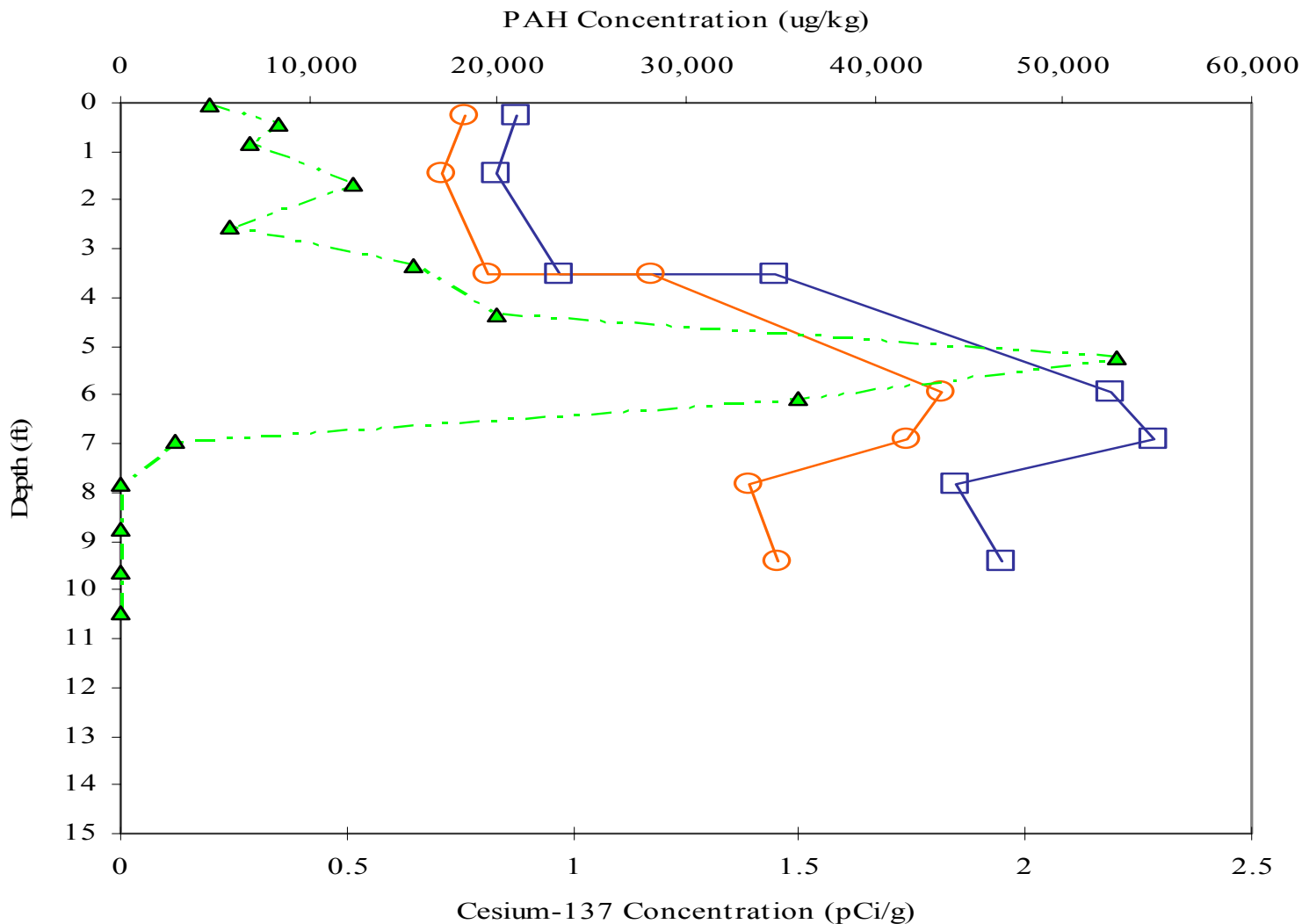
Legend
— □ — Total PAH
— ○ — HMW PAH
— ▲ — Cesium-137

Location

May 1995, River Mile 6.3
TSI Location 272

Notes

1. Total PAH represents the sum of the 16 Priority PAH Pollutants. If one or more of the PAHs were not analyzed, then Total PAH is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero. Note that 2-methylnapthalene, benzo(e)pyrene, and perylene are not included in the summation because they are not a priority pollutant.

2. High Molecular Weight (HMW) PAH represents the sum of the 10 HMW PAH from the Priority PAH Pollutants list. If one or more of the PAHs were not analyzed, then HMW PAH is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.
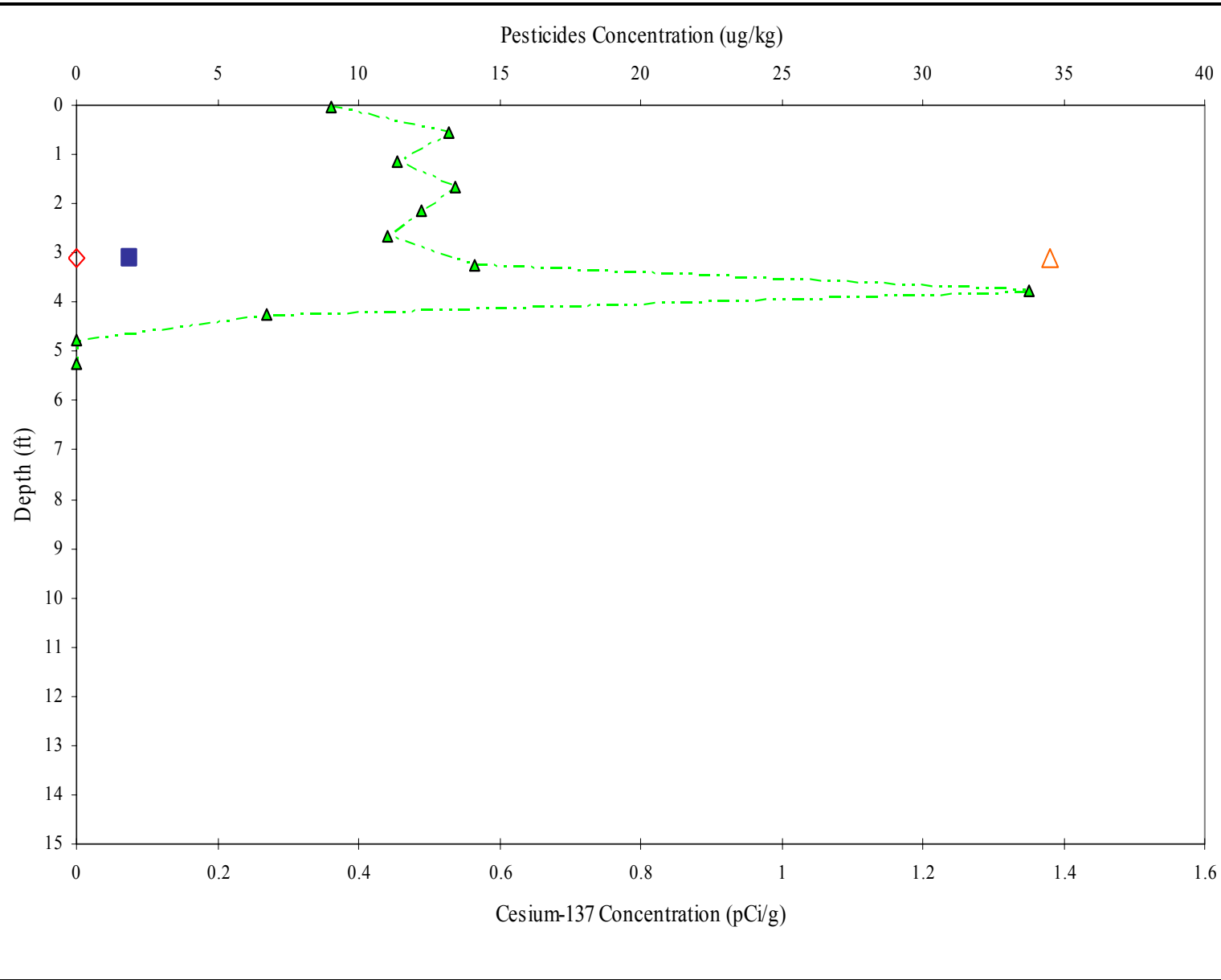
3. Total PAH background concentrations were taken from ATSDR for urban soils. Available online:

http://www.atsdr.cdc.gov/toxprofiles/tp69-c5.pdf.

4. High background includes samples from Passaic Watershed.

Downcore Profile for Total PAH and HMW PAH
(River Mile 6.4)
Lower Passaic River Restoration Project

Figure 4-2m

February 2006
Draft
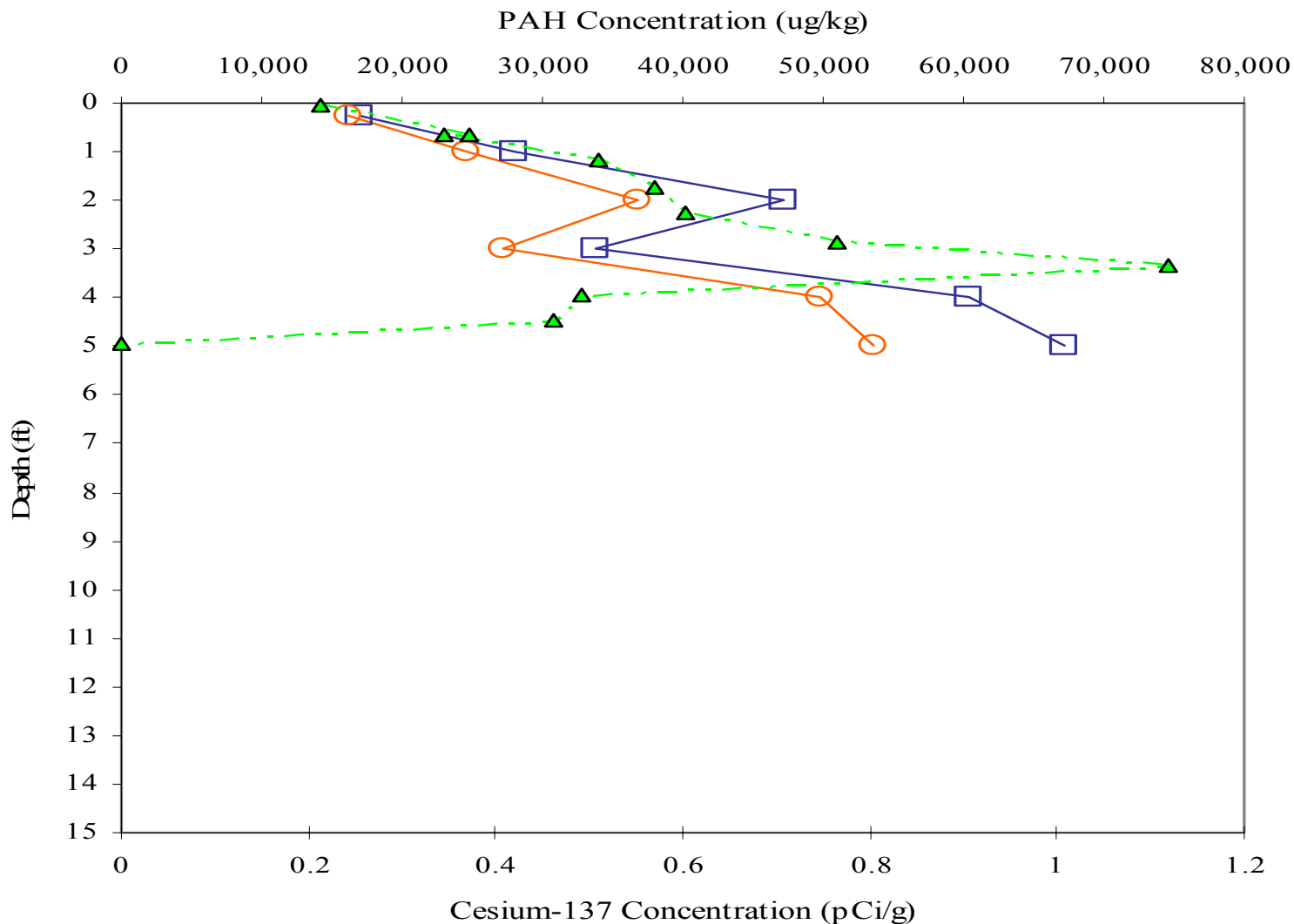
PAH Concentration (ug/kg)

Legend
- Total PAH
- HMW PAH
- Cesium-137

Location

June 1995, River Mile 6.5
TSI Location 275

Notes

1. Total PAH represents the sum of the 16 Priority PAH Pollutants. If one or more of the PAHs were not analyzed, then Total PAH is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero. Note that 2-methylnapthalene, benzo(e)pyrene, and perylene are not included in the summation because they are not a priority pollutant.

2. High Molecular Weight (HMW) PAH represents the sum of the 10 HMW PAH from the Priority PAH Pollutants list. If one or more of the PAHs were not analyzed, then HMW PAH is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.
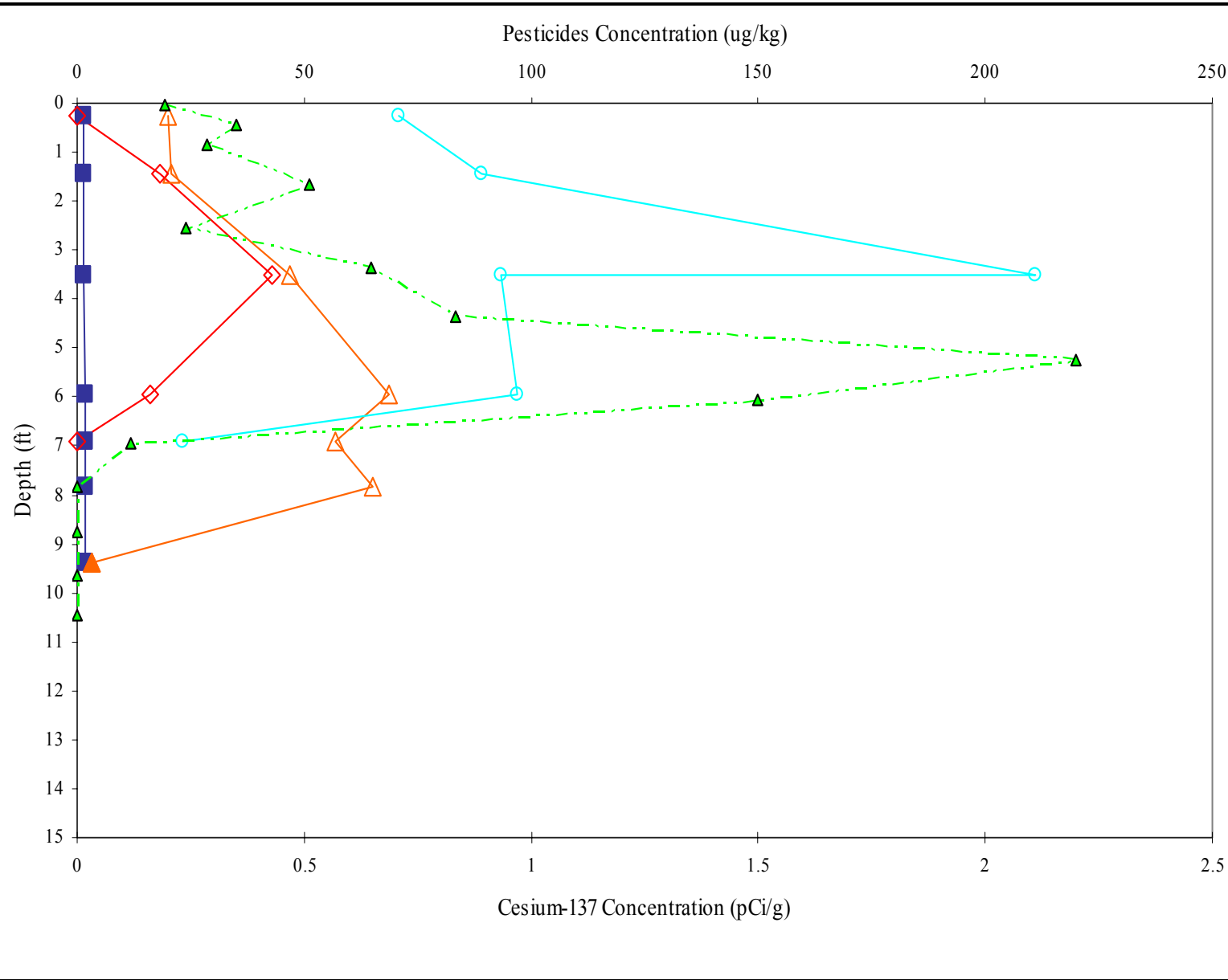
3. Total PAH background concentrations were taken from ATSDR for urban soils. Available online:

http://www.atsdr.cdc.gov/toxprofiles/tp69-c5.pdf.

4. High background includes samples from Passaic Watershed.

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Total PAH and HMW PAH
(River Mile 6.5)
Lower Passaic River Restoration Project

Figure 4-2n

February 2006
Draft
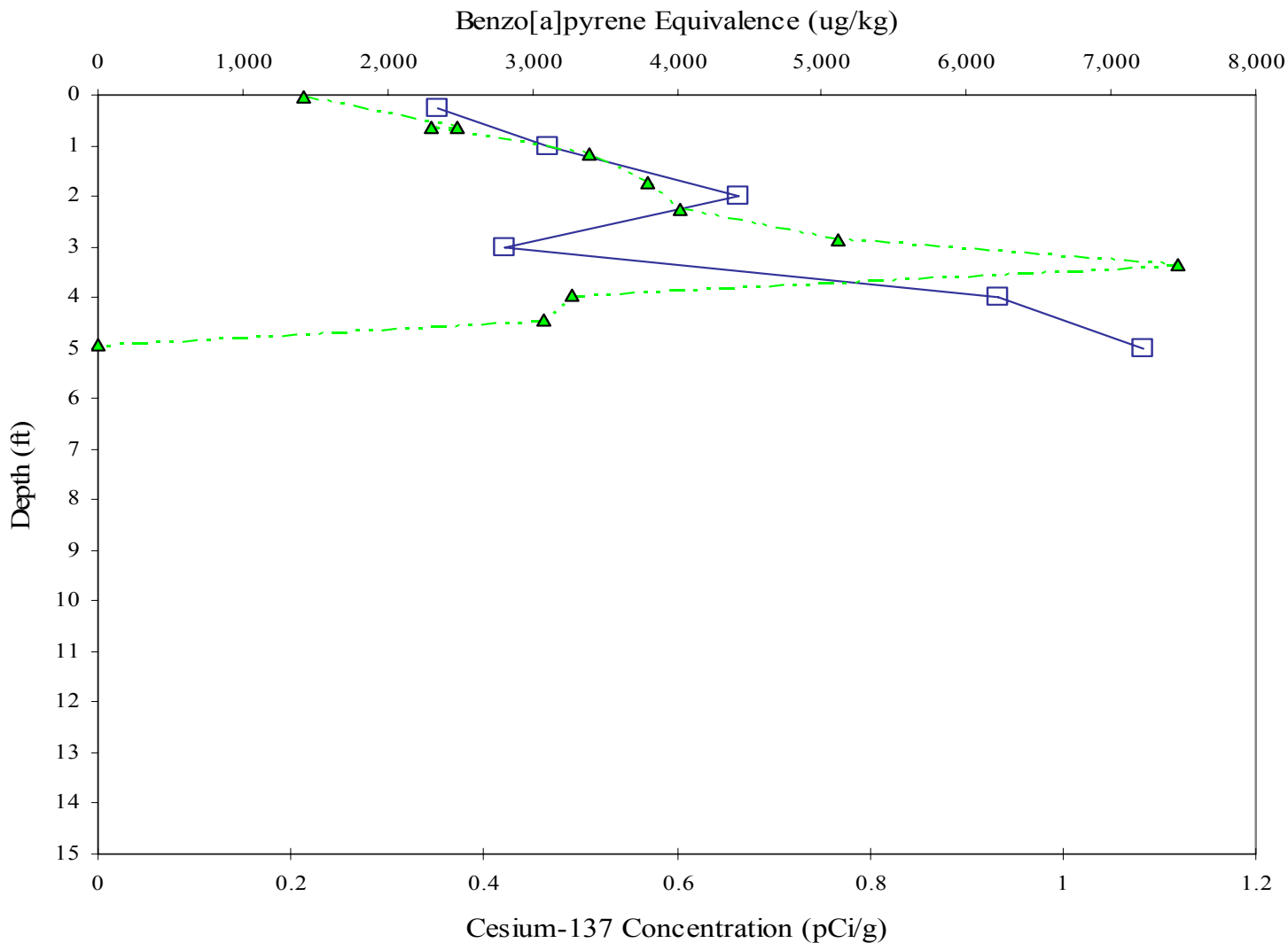
MALCOLM PIRNIE

Legend

Benzo[a]pyrene Equivalence
Cesium-137

Location

April 1995, River Mile 1.5
TSI Location 209

Notes

1. In the USEPA 1986 document "Guidelines for Carcinogen Risk Assessment," seven PAHs are identified as Probable Human Carcinogens (Group B2). These PAHs include benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-c,d]pyrene.

2. Since "Toxicity Equivalency Factors" are not formally defined for these seven PAHs, "estimated order of potential potency" values were used to estimate a weighed-PAH concentration relative to benzo[a]pyrene (USEPA, 1993; EPA/600/R-93/089). For this weighed concentration, non-detect values were set equal to half the reported detection limit.

3. Weighting Values:
benzo[b]fluoranthene = 0.1
benzo[k]fluoranthene = 0.01
benzo[a]pyrene = 1
chrysene = 0.001
dibenz[a,h]anthracene = 1
indeno[1,2,3-c,d]pyrene = 0.1
benzo[a]anthracene = 0.01

4. Benzo[a]pyrene concentrations were taken from ATSDR for urban soils. Available online:

http:www.atsdr.cdc.gov/toxprofiles/tp69.pdf. Note high background includes samples from Passaic Watershed.

Downcore Profile for Benzo[a]pyrene Equivalence (River Mile 1.5)
Lower Passaic River Restoration Project

Figure 4-3a

February 2006
Draft
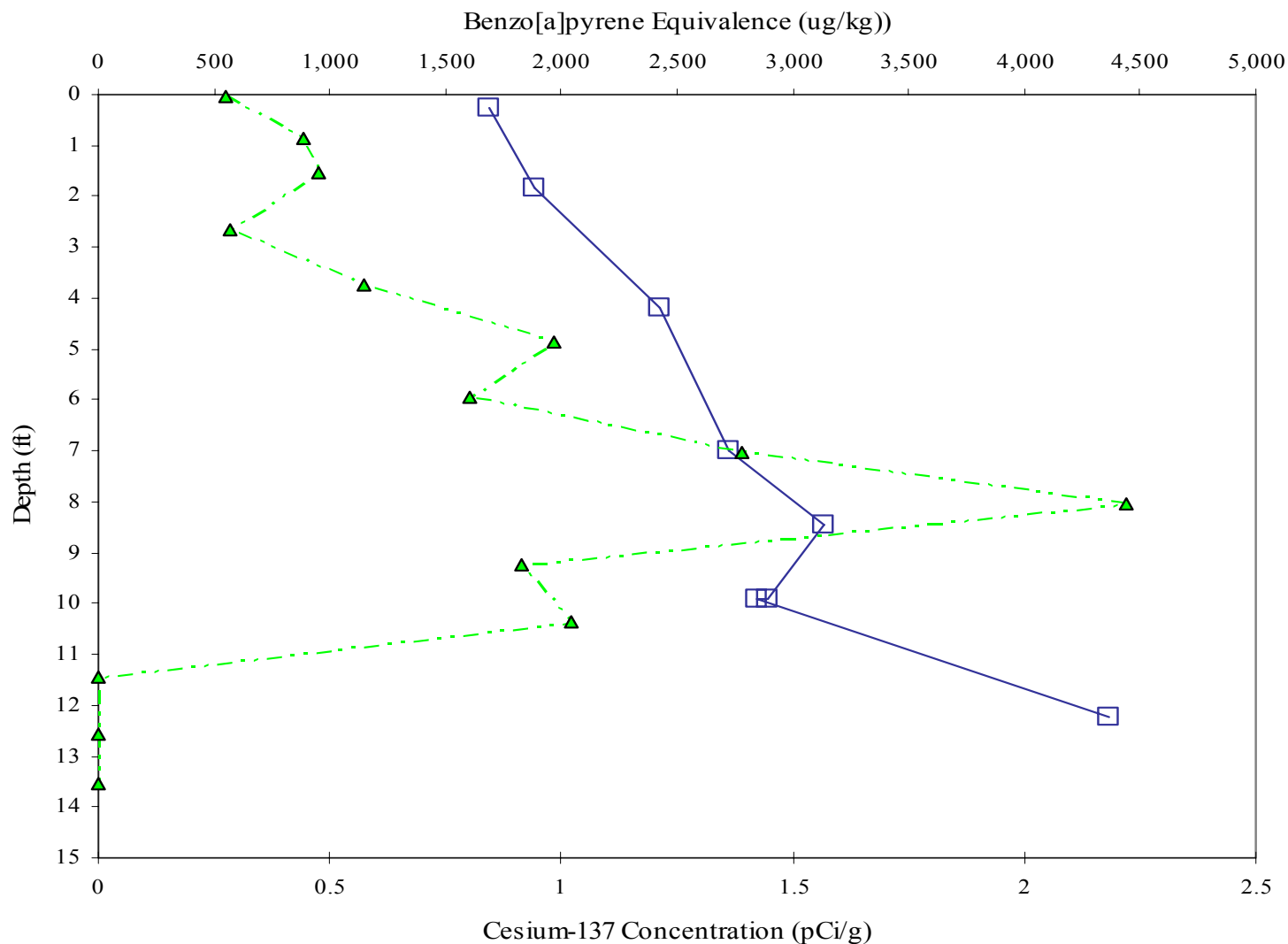
Legend

- Benzo[a]pyrene Equivalence
- Cesium-137

Location

April 1995, River Mile 2.7
TSI Location 222

Notes

1. In the USEPA 1986 document "Guidelines for Carcinogen Risk Assessment," seven PAHs are identified as Probable Human Carcinogens (Group B2). These PAHs include benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-c,d]pyrene.

2. Since "Toxicity Equivalency Factors" are not formally defined for these seven PAHs, "estimated order of potential potency" values were used to estimate a weighed-PAH concentration relative to benzo[a]pyrene (USEPA, 1993; EPA/600/R-93/089). For this weighed concentration, non-detect values were set equal to half the reported detection limit.

3. Weighting Values:
benzo[b]fluoranthene = 0.1
benzo[k]fluoranthene = 0.01
benzo[a]pyrene = 1
chrysene = 0.001
dibenz[a,h]anthracene = 1
indeno[1,2,3-c,d]pyrene = 0.1
benzo[a]anthracene = 0.01

4. Benzo[a]pyrene concentrations were taken from ATSDR for urban soils. Available online:

http:www.atsdr.cdc.gov/toxprofiles/tp69.pdf. Note high background includes samples from Passaic Watershed.

Downcore Profile for Benzo[a]pyrene Equivalence (River Mile 2.7)

Lower Passaic River Restoration Project

Figure 4-3b

February 2006
Draft

Benzo[a]pyrene Equivalence (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Benzo[a]pyrene Equivalence
(River Mile 3.1)

Lower Passaic River Restoration Project

Figure 4-3c

February 2006
Draft

Benzo[a]pyrene Equivalence (ug/kg))

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Benzo[a]pyrene Equivalence
(River Mile 3.1)
Lower Passaic River Restoration Project

Figure 4-3d

February 2006
Draft
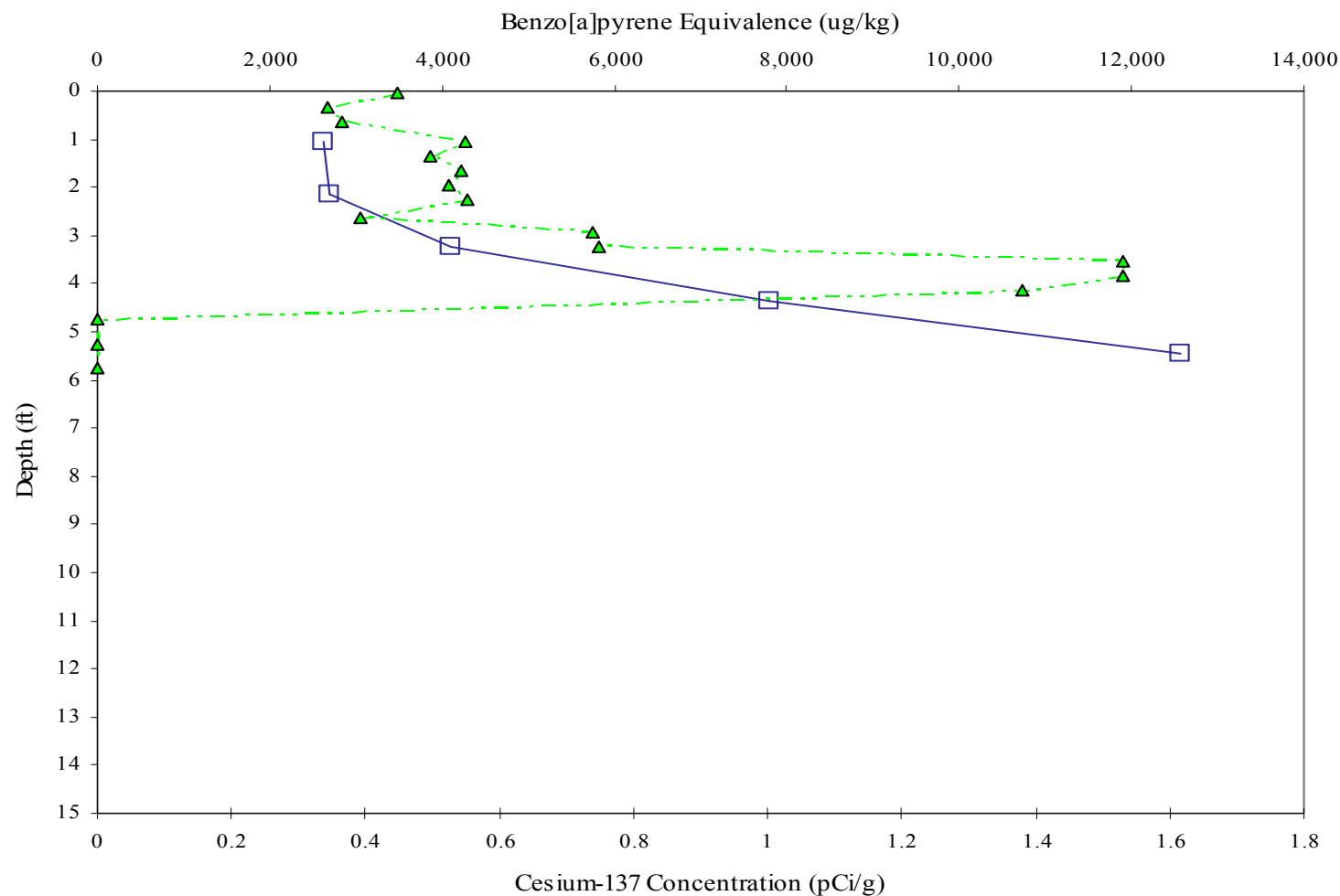
US Army Corps of Engineers

MALCOLM PIRNIE

Legend

- Benzo[a]pyrene Equivalence
- Cesium-137

Location

May 1995, River Mile 3.3
TSI Location 232

Notes

1. In the USEPA 1986 document "Guidelines for Carcinogen Risk Assessment," seven PAHs are identified as Probable Human Carcinogens (Group B2). These PAHs include benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-c,d]pyrene.

2. Since "Toxicity Equivalency Factors" are not formally defined for these seven PAHs, "estimated order of potential potency" values were used to estimate a weighed-PAH concentration relative to benzo[a]pyrene (USEPA, 1993; EPA/600/R-93/089). For this weighed concentration, non-detect values were set equal to half the reported detection limit.

3. Weighting Values:
benzo[b]fluoranthene = 0.1
benzo[k]fluoranthene = 0.01
benzo[a]pyrene = 1
chrysene = 0.001
dibenz[a,h]anthracene = 1
indeno[1,2,3-c,d]pyrene = 0.1
benzo[a]anthracene = 0.01

4. Benzo[a]pyrene concentrations were taken from ATSDR for urban soils. Available online:

http:www.atsdr.cdc.gov/toxprofiles/tp69.pdf. Note high background includes samples from Passaic Watershed.

Downcore Profile for Benzo[a]pyrene Equivalence
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-3e

February 2006
Draft
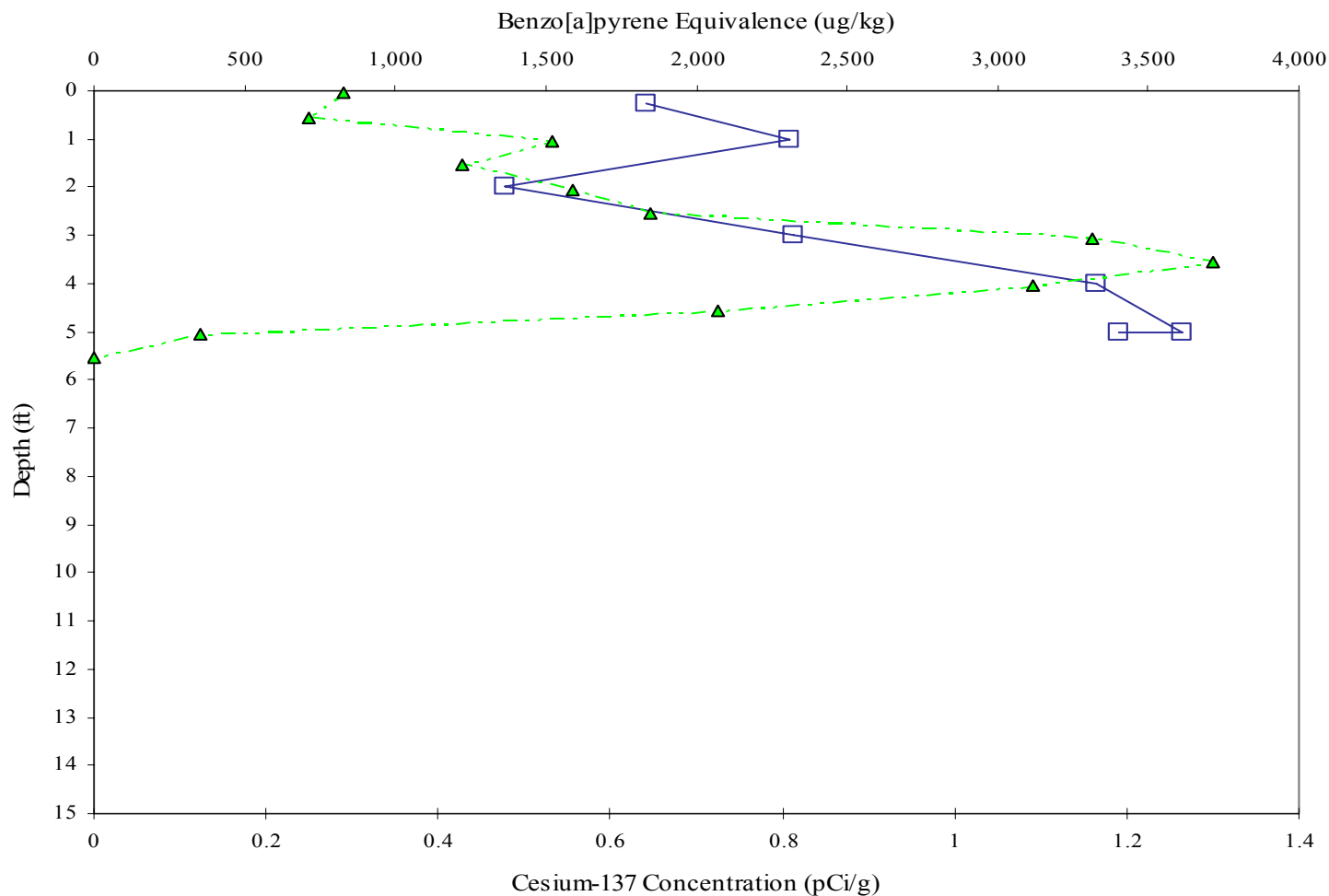
Benzo[a]pyrene Equivalence (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Location

June 1995, River Mile 3.3
TSI Location 286

Notes

1. In the USEPA 1986 document "Guidelines for Carcinogen Risk Assessment," seven PAHs are identified as Probable Human Carcinogens (Group B2). These PAHs include benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-c,d]pyrene.

2. Since "Toxicity Equivalency Factors" are not formally defined for these seven PAHs, "estimated order of potential potency" values were used to estimate a weighed-PAH concentration relative to benzo[a]pyrene (USEPA, 1993; EPA/600/R-93/089). For this weighed concentration, non-detect values were set equal to half the reported detection limit.

3. Weighting Values:
benzo[b]fluoranthene = 0.1
benzo[k]fluoranthene = 0.01
benzo[a]pyrene = 1
chrysene = 0.001
dibenz[a,h]anthracene = 1
indeno[1,2,3-c,d]pyrene = 0.1
benzo[a]anthracene = 0.01

4. Benzo[a]pyrene concentrations were taken from ATSDR for urban soils. Available online:

http:www.atsdr.cdc.gov/toxprofiles/tp69.pdf. Note high background includes samples from Passaic Watershed.

Downcore Profile for Benzo[a]pyrene Equivalence
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-3f

February 2006
Draft
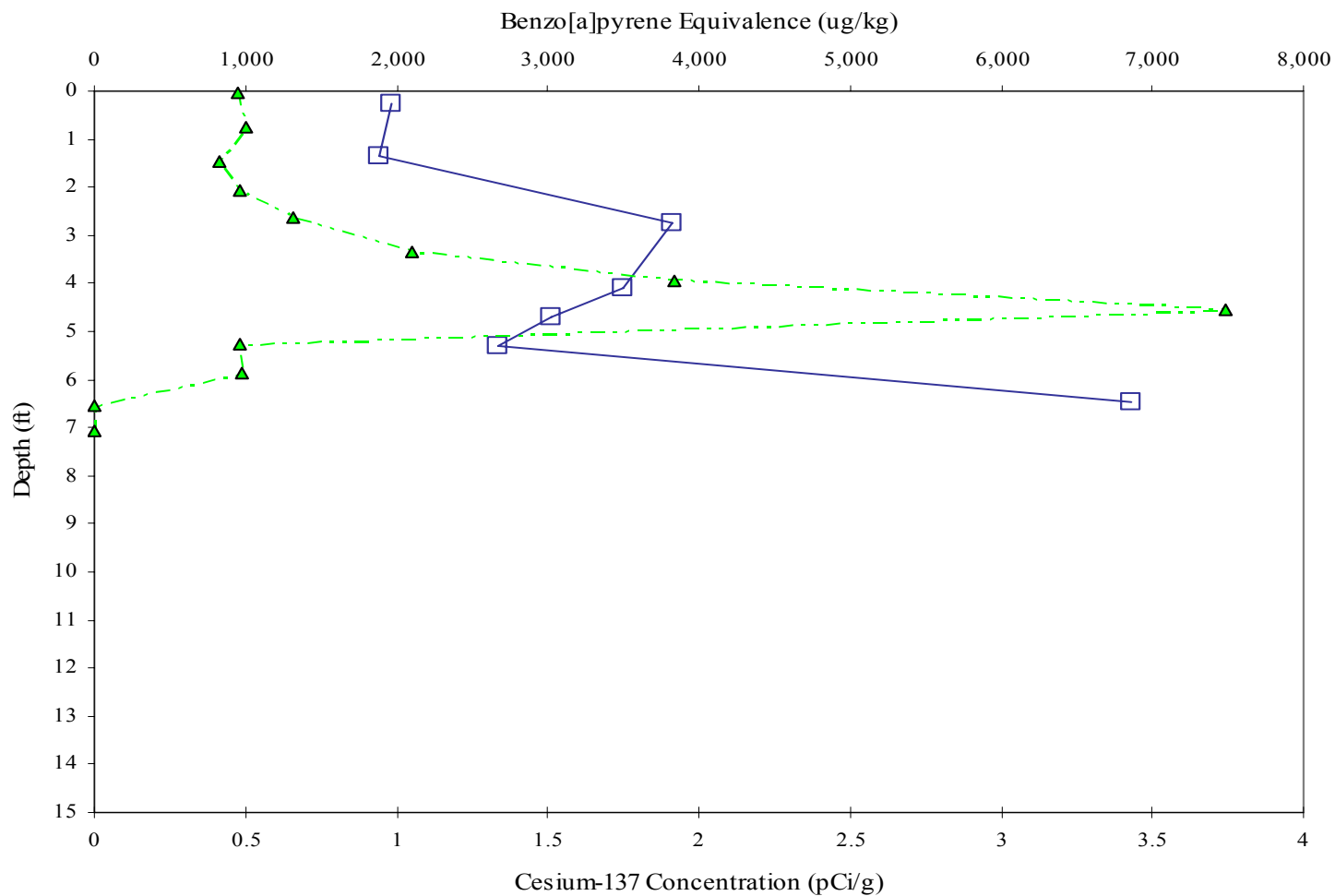
US Army Corps of Engineers

MALCOLM PIRNIE

Benzo[a]pyrene Equivalence (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Location

May 1995, River Mile 3.6
TSI Location 235

Notes

1. In the USEPA 1986 document "Guidelines for Carcinogen Risk Assessment," seven PAHs are identified as Probable Human Carcinogens (Group B2). These PAHs include benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-c,d]pyrene.

2. Since "Toxicity Equivalency Factors" are not formally defined for these seven PAHs, "estimated order of potential potency" values were used to estimate a weighed-PAH concentration relative to benzo[a]pyrene (USEPA, 1993; EPA/600/R-93/089). For this weighed concentration, non-detect values were set equal to half the reported detection limit.

3. Weighting Values:
benzo[b]fluoranthene = 0.1
benzo[k]fluoranthene = 0.01
benzo[a]pyrene = 1
chrysene = 0.001
dibenz[a,h]anthracene = 1
indeno[1,2,3-c,d]pyrene = 0.1
benzo[a]anthracene = 0.01

4. Benzo[a]pyrene concentrations were taken from ATSDR for urban soils. Available online:

http:www.atsdr.cdc.gov/toxprofiles/tp69 .pdf. Note high background includes samples from Passaic Watershed.

Downcore Profile for Benzo[a]pyrene Equivalence
(River Mile 3.6)
Lower Passaic River Restoration Project

Figure 4-3g

February 2006
Draft

MALCOLM
PIRNIE

Downcore Profile for Benzo[a]pyrene Equivalence
(River Mile 4.0)
Lower Passaic River Restoration Project

Figure 4-3h

February 2006
Draft

Legend

- Benzo[a]pyrene Equivalence
- Cesium-137

Location

May 1995, River Mile 4.0
TSI Location 241

Notes

1. In the USEPA 1986 document "Guidelines for Carcinogen Risk Assessment," seven PAHs are identified as Probable Human Carcinogens (Group B2). These PAHs include benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-c,d]pyrene.

2. Since "Toxicity Equivalency Factors" are not formally defined for these seven PAHs, "estimated order of potential potency" values were used to estimate a weighed-PAH concentration relative to benzo[a]pyrene (USEPA, 1993; EPA/600/R-93/089). For this weighed concentration, non-detect values were set equal to half the reported detection limit.

3. Weighting Values:
benzo[b]fluoranthene = 0.1
benzo[k]fluoranthene = 0.01
benzo[a]pyrene = 1
chrysene = 0.001
dibenz[a,h]anthracene = 1
indeno[1,2,3-c,d]pyrene = 0.1
benzo[a]anthracene = 0.01

4. Benzo[a]pyrene concentrations were taken from ATSDR for urban soils. Available online:

http:www.atsdr.cdc.gov/toxprofiles/tp69.pdf. Note high background includes samples from Passaic Watershed.

Benzo[a]pyrene Equivalence (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Benzo[a]pyrene Equivalence
(River Mile 4.5)
Lower Passaic River Restoration Project

Figure 4-3i

February 2006
Draft

Benzo[a]pyrene Equivalence (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Benzo[a]pyrene Equivalence
(River Mile 4.7)

Lower Passaic River Restoration Project

Figure 4-3j

February 2006
Draft

Benzo[a]pyrene Equivalence (ug/kg))

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Benzo[a]pyrene Equivalence
(River Mile 4.9)
Lower Passaic River Restoration Project

Figure 4-3k

February 2006
Draft
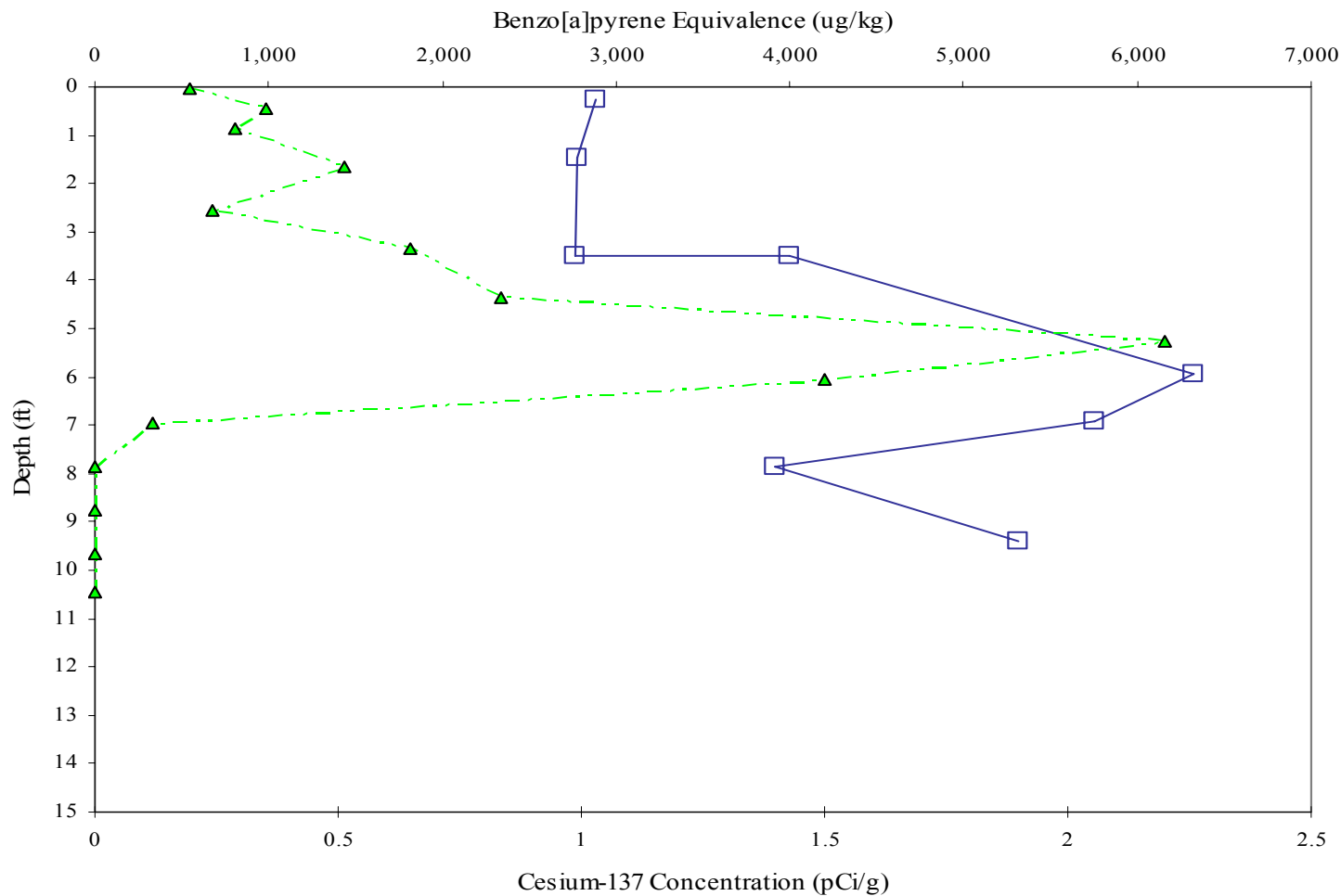
US Army Corps
of Engineers®

MALCOLM
PIRNIE

Benzo[a]pyrene Equivalence (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Location

May 1995, River Mile 6.3
TSI Location 272

Notes

1. In the USEPA 1986 document "Guidelines for Carcinogen Risk Assessment," seven PAHs are identified as Probable Human Carcinogens (Group B2). These PAHs include benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-c,d]pyrene.

2. Since "Toxicity Equivalency Factors" are not formally defined for these seven PAHs, "estimated order of potential potency" values were used to estimate a weighed-PAH concentration relative to benzo[a]pyrene (USEPA, 1993; EPA/600/R-93/089). For this weighed concentration, non-detect values were set equal to half the reported detection limit.

3. Weighting Values:
benzo[b]fluoranthene = 0.1
benzo[k]fluoranthene = 0.01
benzo[a]pyrene = 1
chrysene = 0.001
dibenz[a,h]anthracene = 1
indeno[1,2,3-c,d]pyrene = 0.1
benzo[a]anthracene = 0.01

4. Benzo[a]pyrene concentrations were taken from ATSDR for urban soils. Available online:

http:www.atsdr.cdc.gov/toxprofiles/tp69.pdf. Note high background includes samples from Passaic Watershed.

Downcore Profile for Benzo[a]pyrene Equivalence
(River Mile 6.3)
Lower Passaic River Restoration Project

Figure 4-3l

February 2006
Draft

US Army Corps of Engineers

MALCOLM PIRNIE

Downcore Profile for Benzo[a]pyrene Equivalence
(River Mile 6.4)
Lower Passaic River Restoration Project

Figure 4-3m

February 2006
Draft

Legend

- □ Benzo[a]pyrene Equivalence
- △ Cesium-137

Location

June 1995, River Mile 6.4
TSI Location 296

Notes

1. In the USEPA 1986 document "Guidelines for Carcinogen Risk Assessment," seven PAHs are identified as Probable Human Carcinogens (Group B2). These PAHs include benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-c,d]pyrene.

2. Since "Toxicity Equivalency Factors" are not formally defined for these seven PAHs, "estimated order of potential potency" values were used to estimate a weighed-PAH concentration relative to benzo[a]pyrene (USEPA, 1993; EPA/600/R-93/089). For this weighed concentration, non-detect values were set equal to half the reported detection limit.

3. Weighting Values:
benzo[b]fluoranthene = 0.1
benzo[k]fluoranthene = 0.01
benzo[a]pyrene = 1
chrysene = 0.001
dibenz[a,h]anthracene = 1
indeno[1,2,3-c,d]pyrene = 0.1
benzo[a]anthracene = 0.01

4. Benzo[a]pyrene concentrations were taken from ATSDR for urban soils. Available online:

http:www.atsdr.cdc.gov/toxprofiles/tp69.pdf. Note high background includes samples from Passaic Watershed.

Benzo[a]pyrene Equivalence (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Location

June 1995, River Mile 6.5
TSI Location 275

Notes

1. In the USEPA 1986 document "Guidelines for Carcinogen Risk Assessment," seven PAHs are identified as Probable Human Carcinogens (Group B2). These PAHs include benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-c,d]pyrene.

2. Since "Toxicity Equivalency Factors" are not formally defined for these seven PAHs, "estimated order of potential potency" values were used to estimate a weighed-PAH concentration relative to benzo[a]pyrene (USEPA, 1993; EPA/600/R-93/089). For this weighed concentration, non-detect values were set equal to half the reported detection limit.

3. Weighting Values:
benzo[b]fluoranthene = 0.1
benzo[k]fluoranthene = 0.01
benzo[a]pyrene = 1
chrysene = 0.001
dibenz[a,h]anthracene = 1
indeno[1,2,3-c,d]pyrene = 0.1
benzo[a]anthracene = 0.01

4. Benzo[a]pyrene concentrations were taken from ATSDR for urban soils. Available online:

http:www.atsdr.cdc.gov/toxprofiles/tp69.pdf. Note high background includes samples from Passaic Watershed.

Downcore Profile for Benzo[a]pyrene Equivalence (River Mile 6.5)	Figure 4-3n
Lower Passaic River Restoration Project	February 2006 Draft

Pesticides Concentration (ug/kg)

Legend

- Aldrin Detect
- Aldrin Nondetect
- Dieldrin Detect
- Total Endrin
- Total Chlordane
- Cesium-137

Location

April 1995, River Mile 1.5
TSI Location 209

Notes

1. For Aldrin and Dieldrin, non-detected values (lab qualifier containing a U) are plotted as half the reported concentration.

2. Total Chlordane represents the sum of the cis-isomer and trans-isomer. If one of the isomers was not analyzed, then Total Chlordane is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

3. Total Endrin represents the sum of endrin ketone, endrin, and endrin aldehyde. If one or more of the analytes were not analyzed, then Total Endrin is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Pesticides
(River Mile 1.5)
Lower Passaic River Restoration Project

Figure 4-4a

February 2006
Draft
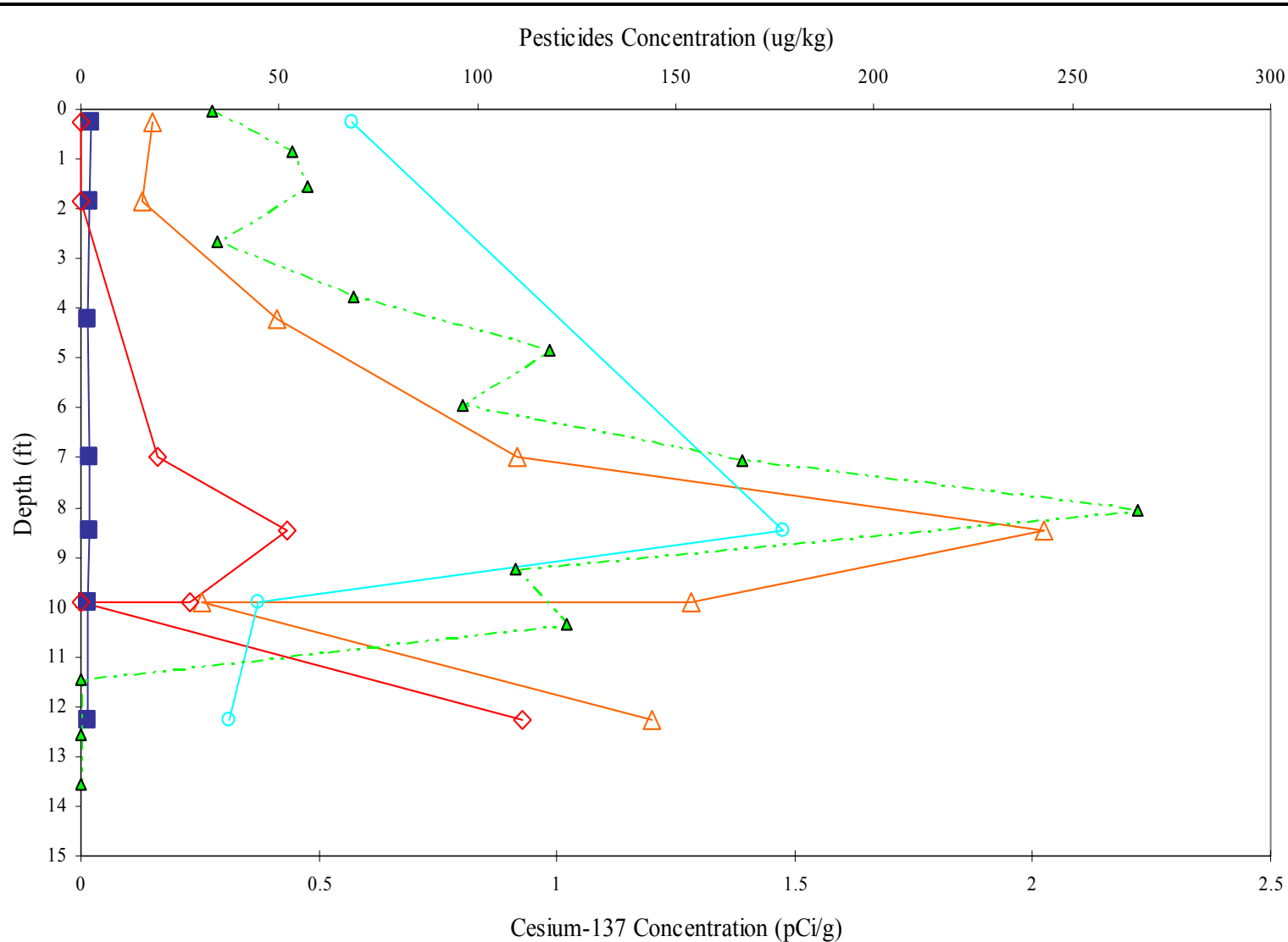
MALCOLM PIRNIE

Legend

- Aldrin Detect
- Aldrin Nondetect
- Dieldrin Detect
- Total Endrin
- Total Chlordane
- Cesium-137

Location

April 1995, River Mile 2.7
TSI Location 222

Notes

1. For Aldrin and Dieldrin, non-detected values (lab qualifier containing a U) are plotted as half the reported concentration.

2. Total Chlordane represents the sum of the cis-isomer and trans-isomer. If one of the isomers was not analyzed, then Total Chlordane is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

3. Total Endrin represents the sum of endrin ketone, endrin, and endrin aldehyde. If one or more of the analytes were not analyzed, then Total Endrin is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

Downcore Profile for Pesticides
(River Mile 2.7)
Lower Passaic River Restoration Project

Figure 4-4b

February 2006
Draft

US Army Corps of Engineers

MALCOLM PIRNIE

Pesticides Concentration (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Downcore Profile for Pesticides
(River Mile 3.1)
Lower Passaic River Restoration Project

Figure 4-4c

February 2006
Draft

Legend

- Aldrin Detect
- Aldrin Nondetect
- Dieldrin Detect
- Dieldrin Nondetect
- Total Endrin
- Total Chlordane
- Cesium-137

Location

May 1995, River Mile 3.1
TSI Location 230

Notes

1. For Aldrin and Dieldrin, non-detected values (lab qualifier containing a U) are plotted as half the reported concentration.

2. Total Chlordane represents the sum of the cis-isomer and trans-isomer. If one of the isomers was not analyzed, then Total Chlordane is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

3. Total Endrin represents the sum of endrin ketone, endrin, and endrin aldehyde. If one or more of the analytes were not analyzed, then Total Endrin is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

Downcore Profile for Pesticides (River Mile 3.1)

Lower Passaic River Restoration Project

Figure 4-4d

February 2006
Draft

Pesticides Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Legend

- Aldrin Detect
- Aldrin Nondetect
- Dieldrin Detect
- Total Endrin
- Total Chlordane
- Cesium-137

Location

May 1995, River Mile 3.3
TSI Location 232

Notes

1. For Aldrin and Dieldrin, non-detected values (lab qualifier containing a U) are plotted as half the reported concentration.

2. Total Chlordane represents the sum of the cis-isomer and trans-isomer. If one of the isomers was not analyzed, then Total Chlordane is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

3. Total Endrin represents the sum of endrin ketone, endrin, and endrin aldehyde. If one or more of the analytes were not analyzed, then Total Endrin is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

Downcore Profile for Pesticides
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-4e

February 2006
Draft
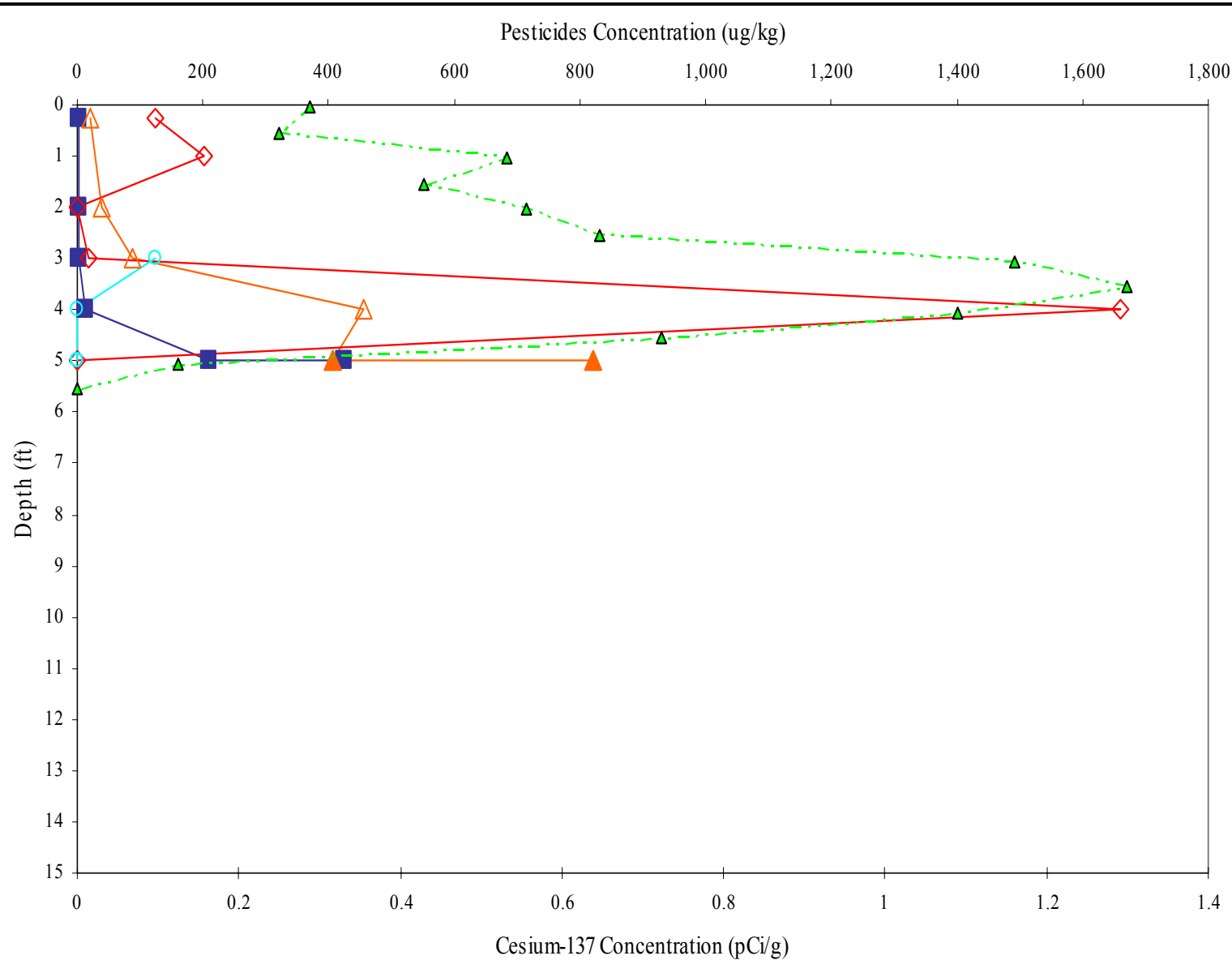
Legend

- □— Aldrin Detect
- ■ Aldrin Nondetect
- △— Dieldrin Detect
- ▲ Dieldrin Nondetect
- ◇— Total Endrin
- ○— Total Chlordane
- ▲–·– Cesium-137

Location

June 1995, River Mile 3.3
TSI Location 286

Notes

1. For Aldrin and Dieldrin, non-detected values (lab qualifier containing a U) are plotted as half the reported concentration.

2. Total Chlordane represents the sum of the cis-isomer and trans-isomer. If one of the isomers was not analyzed, then Total Chlordane is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

3. Total Endrin represents the sum of endrin ketone, endrin, and endrin aldehyde. If one or more of the analytes were not analyzed, then Total Endrin is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

Downcore Profile for Pesticides
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-4f

February 2006
Draft
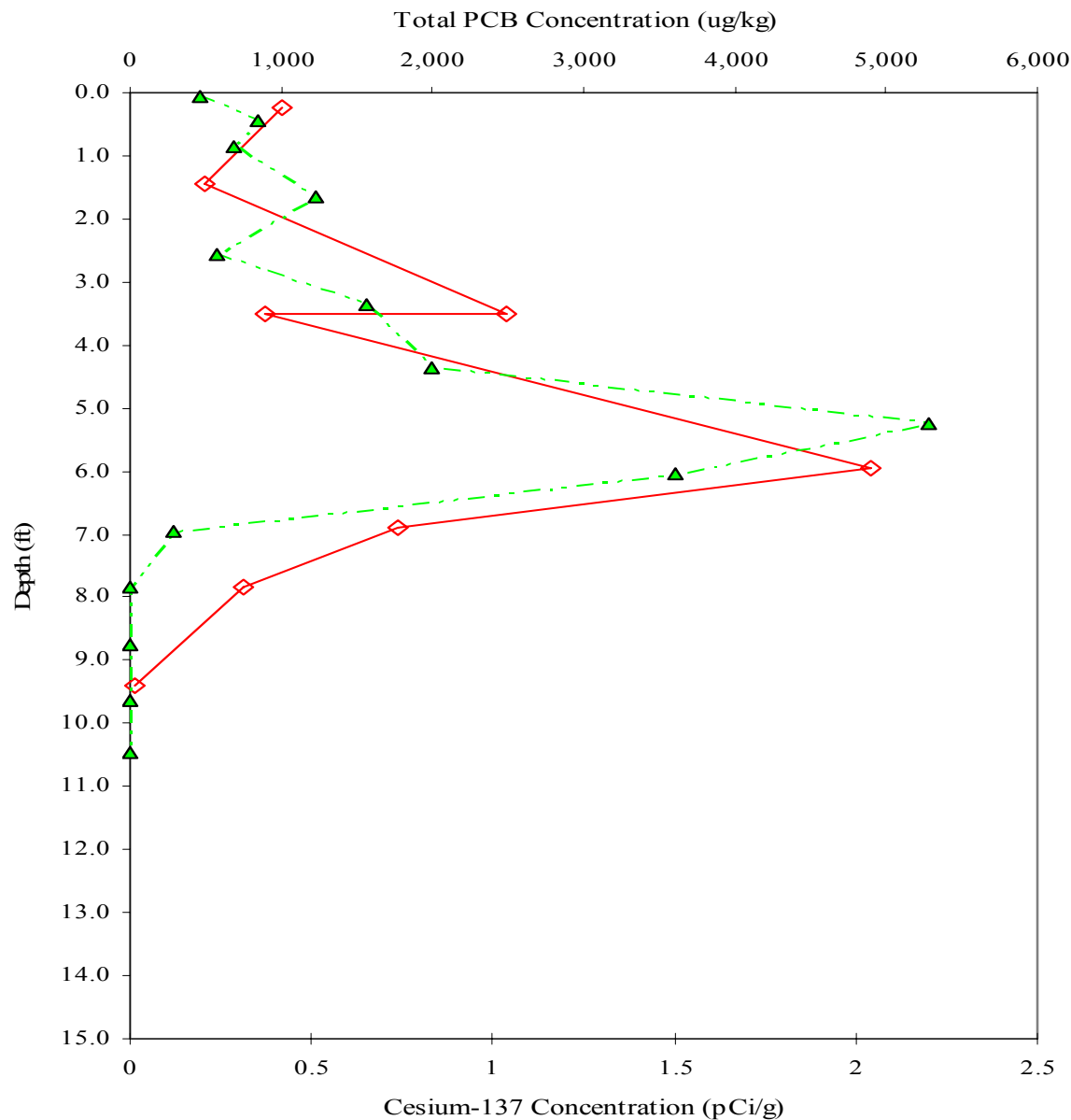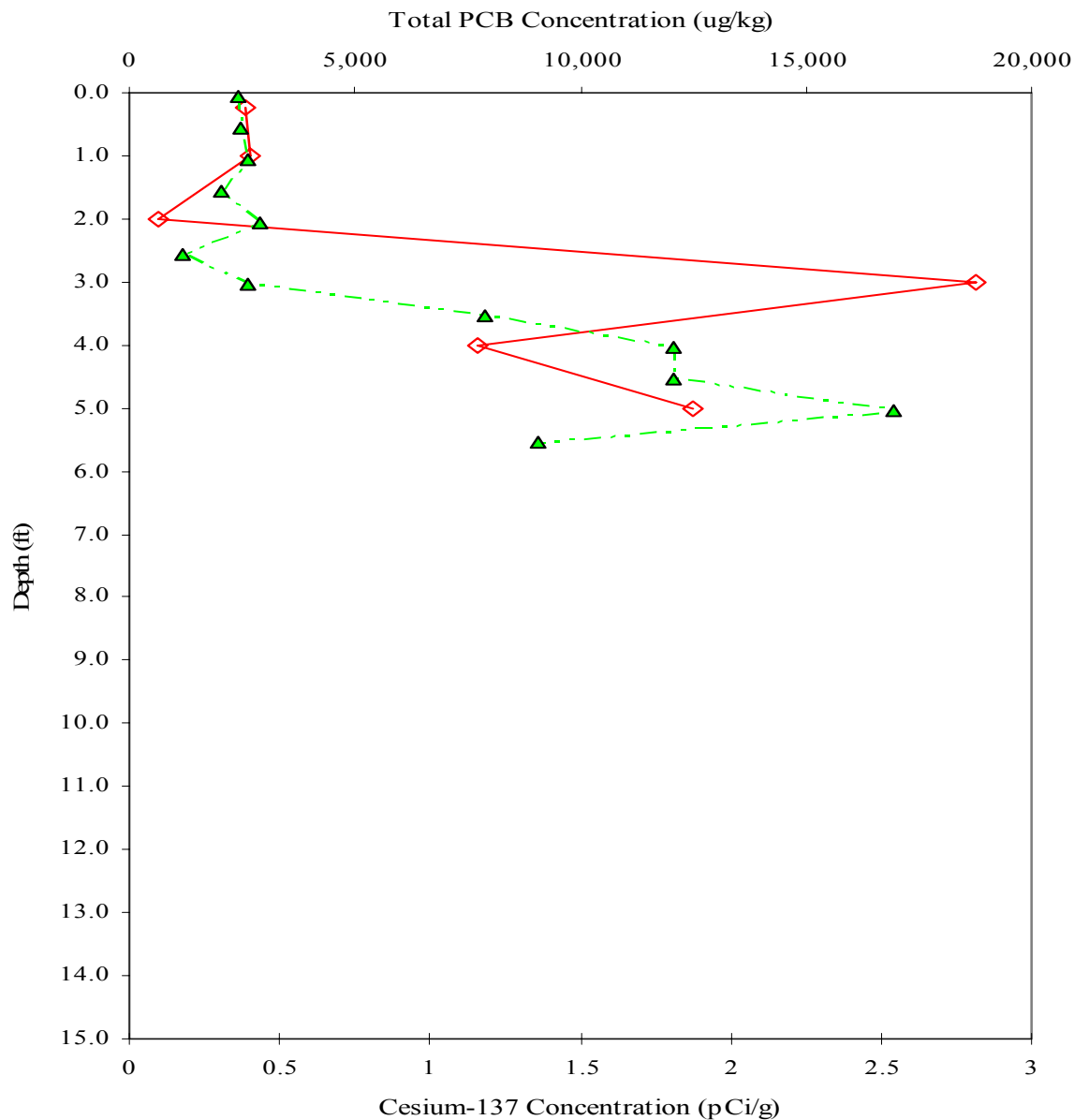
Downcore Profile for Total Pesticides
(River Mile 3.6)
Lower Passaic River Restoration Project

Figure 4-4g

February 2006
Draft

Legend

- Aldrin Detect
- Aldrin Nondetect
- Dieldrin Detect
- Total Endrin
- Total Chlordane
- Cesium-137

Location

May 1995, River Mile 3.6
TSI Location 235

Notes

1. For Aldrin and Dieldrin, non-detected values (lab qualifier containing a U) are plotted as half the reported concentration.

2. Total Chlordane represents the sum of the cis-isomer and trans-isomer. If one of the isomers was not analyzed, then Total Chlordane is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

3. Total Endrin represents the sum of endrin ketone, endrin, and endrin aldehyde. If one or more of the analytes were not analyzed, then Total Endrin is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

Downcore Profile for Pesticides
(River Mile 4.0)
Lower Passaic River Restoration Project

Figure 4-4h

February 2006
Draft

Legend

- Aldrin Detect
- Aldrin Nondetect
- Dieldrin Detect
- Total Endrin
- Total Chlordane
- Cesium-137

Location

May 1995, River Mile 4.0
TSI Location 241

Notes

1. For Aldrin and Dieldrin, non-detected values (lab qualifier containing a U) are plotted as half the reported concentration.

2. Total Chlordane represents the sum of the cis-isomer and trans-isomer. If one of the isomers was not analyzed, then Total Chlordane is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

3. Total Endrin represents the sum of endrin ketone, endrin, and endrin aldehyde. If one or more of the analytes were not analyzed, then Total Endrin is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

Figure 4-4i

Downcore Profile for Pesticides
(River Mile 4.5)
Lower Passaic River Restoration Project

February 2006
Draft

Legend

- Aldrin Detect
- Aldrin Nondetect
- Dieldrin Detect
- Dieldrin Nondetect
- Total Endrin
- Total Chlordane
- Cesium-137

Location

May 1995, River Mile 4.5
TSI Location 248

Notes

1. For Aldrin and Dieldrin, non-detected values (lab qualifier containing a U) are plotted as half the reported concentration.

2. Total Chlordane represents the sum of the cis-isomer and trans-isomer. If one of the isomers was not analyzed, then Total Chlordane is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

3. Total Endrin represents the sum of endrin ketone, endrin, and endrin aldehyde. If one or more of the analytes were not analyzed, then Total Endrin is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

Downcore Profile for Pesticides
(River Mile 4.7)
Lower Passaic River Restoration Project

Figure 4-4j

February 2006
Draft

Pesticides Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Pesticides
(River Mile 4.9)
Lower Passaic River Restoration Project

Figure 4-4k

February 2006
Draft

Downcore Profile for Pesticides
(River Mile 6.3)
Lower Passaic River Restoration Project

Figure 4-4I

February 2006
Draft

Downcore Profile for Pesticides
(River Mile 6.4)
Lower Passaic River Restoration Project

Figure 4-4m

February 2006
Draft
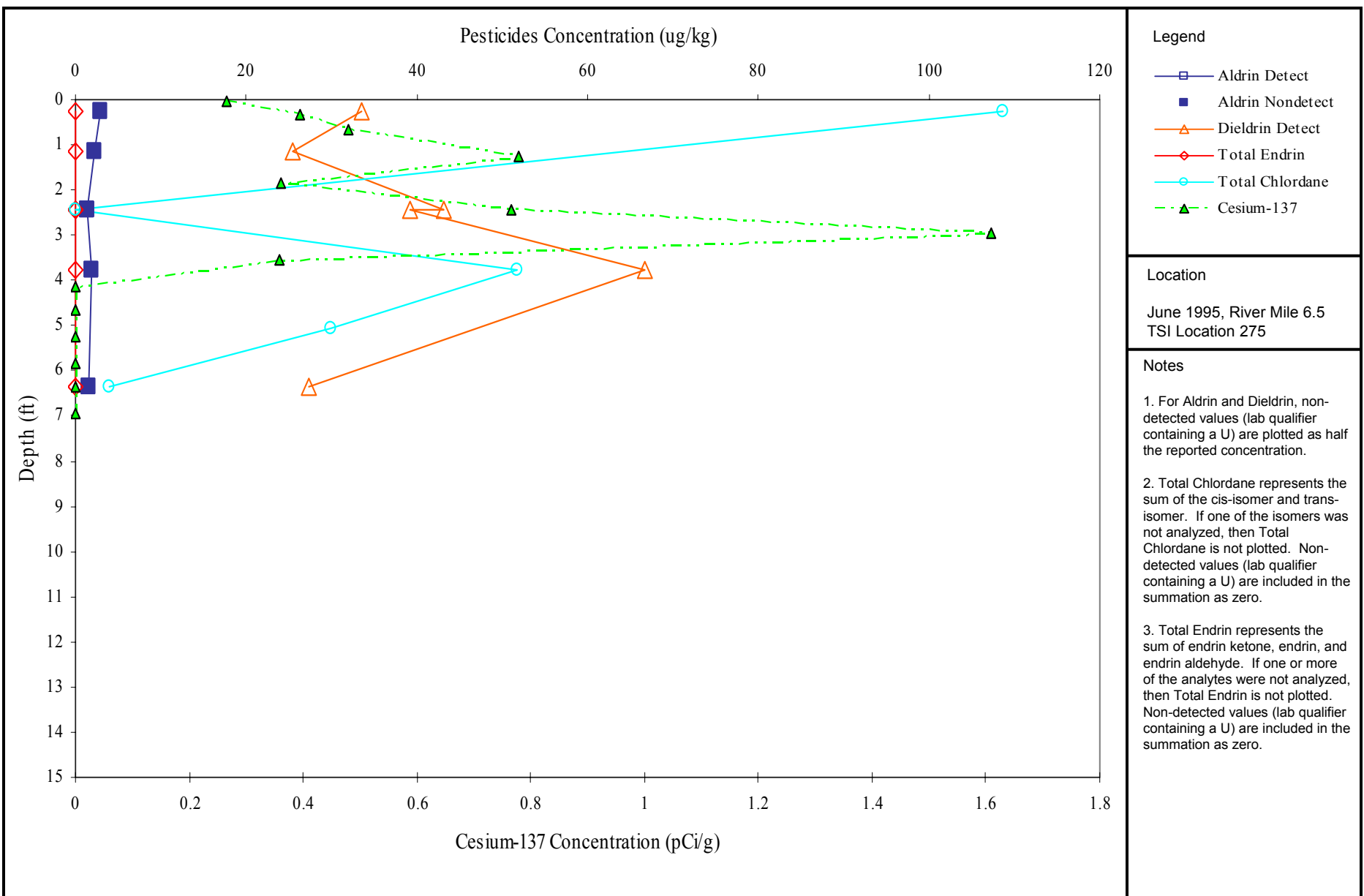
Pesticides Concentration (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Location

June 1995, River Mile 6.5
TSI Location 275

Notes

1. For Aldrin and Dieldrin, non-detected values (lab qualifier containing a U) are plotted as half the reported concentration.

2. Total Chlordane represents the sum of the cis-isomer and trans-isomer. If one of the isomers was not analyzed, then Total Chlordane is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

3. Total Endrin represents the sum of endrin ketone, endrin, and endrin aldehyde. If one or more of the analytes were not analyzed, then Total Endrin is not plotted. Non-detected values (lab qualifier containing a U) are included in the summation as zero.

Downcore Profile for Pesticides
(River Mile 6.5)
Lower Passaic River Restoration Project

Figure 4-4n

February 2006
Draft

2,3,7,8-TCDD (ug/kg) and Total DDT (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Legend

- □ 2,3,7,8-TCDD
- ◇ Total DDT
- ▲ Cesium-137

Location

April 1995, River Mile 1.5
TSI Location 209

Notes:

Total DDT represents the sum of the three 4,4'-isomers (whenever possible).

Nondetected values were incorporated into the sum as half the reported detection limit.

Nondetected concentrations of 2,3,7,8-TCDD were not reported at this coring location.

Downcore Profile for 2,3,7,8-TCDD and Total DDT
(River Mile 1.5)
Lower Passaic River Restoration Project

Figure 4-5a

February 2006
Draft
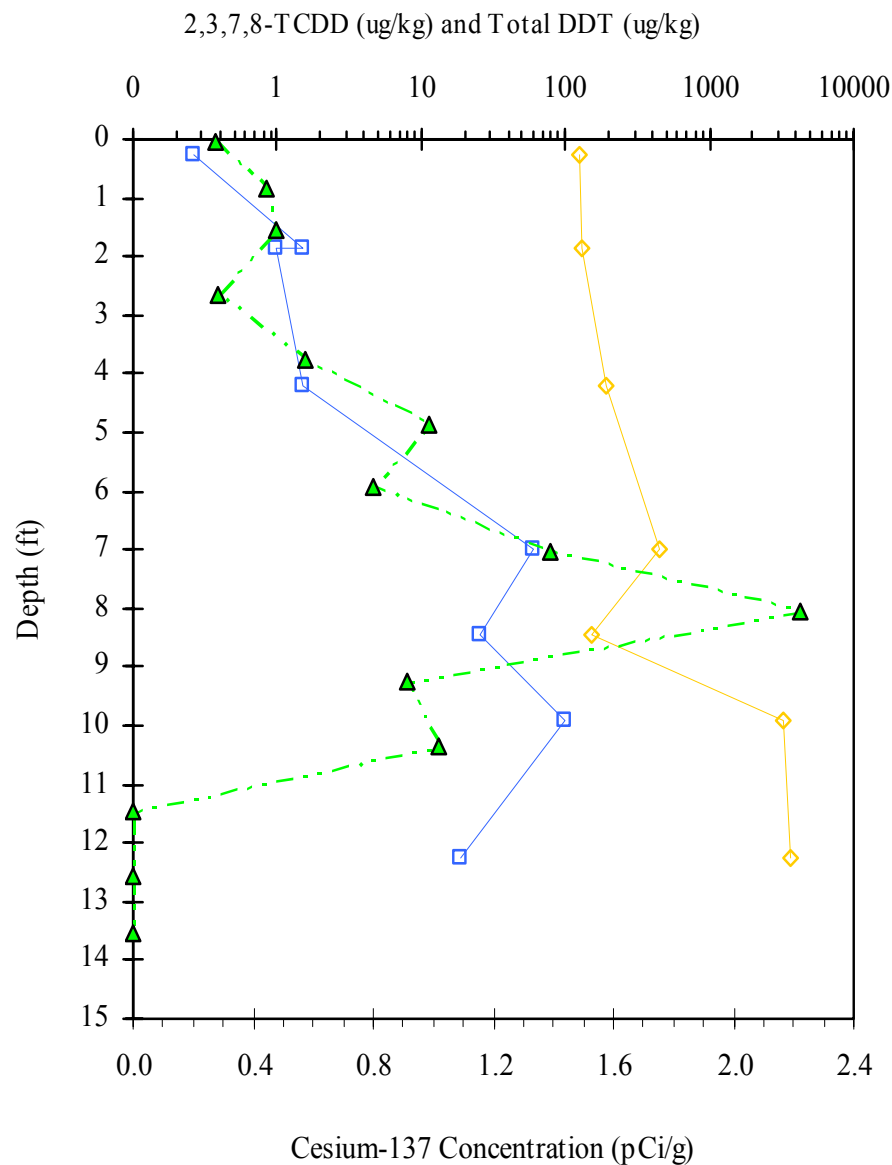
US Army Corps
of Engineers®

MALCOLM
PIRNIE

2,3,7,8-TCDD (ug/kg) and Total DDT (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Location

April 1995, River Mile 2.7
TSI Location 222

Notes:

Total DDT represents the sum of the three 4,4'-isomers (whenever possible).

Nondetected values were incorporated into the sum as half the reported detection limit.

Nondetected concentrations of 2,3,7,8-TCDD were not reported at this coring location.

Downcore Profile for 2,3,7,8-TCDD and Total DDT
(River Mile 2.7)
Lower Passaic River Restoration Project

Figure 4-5b

February 2006
Draft
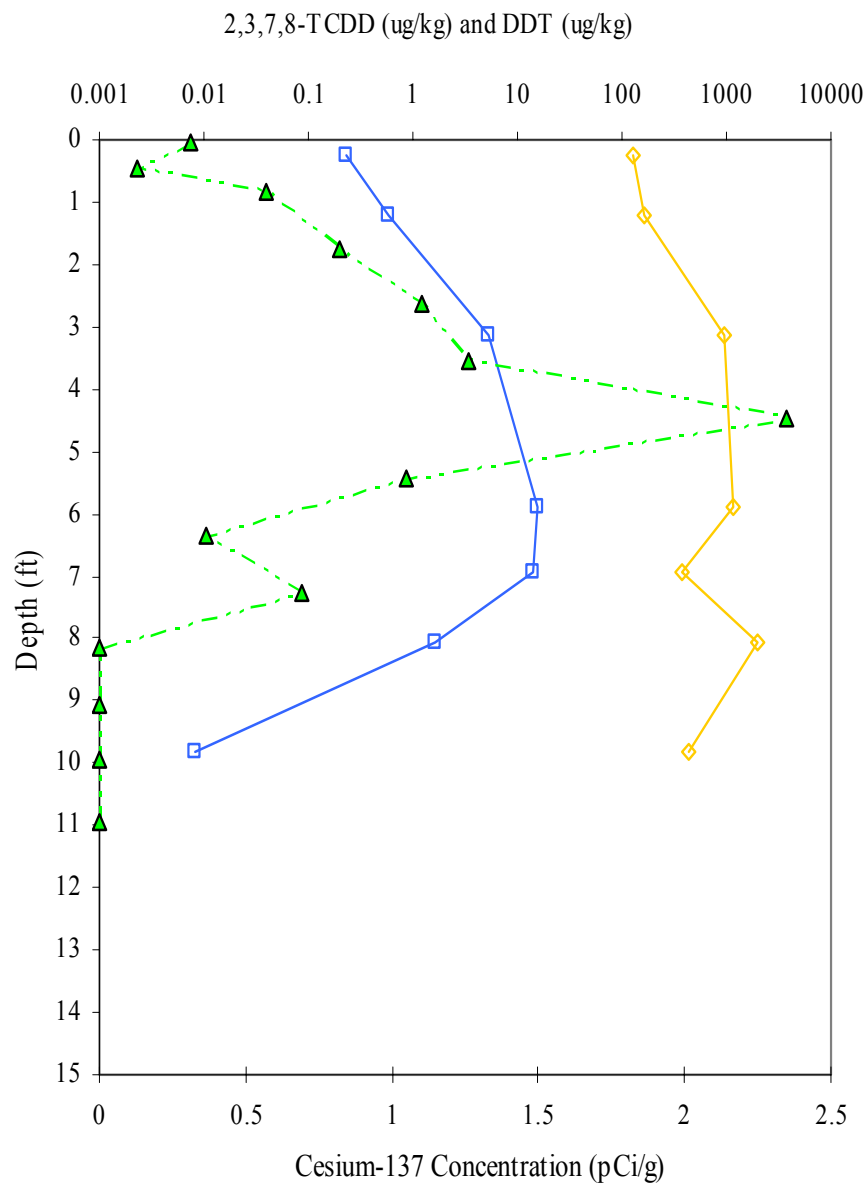
MALCOLM PIRNIE

2,3,7,8-TCDD (ug/kg) and DDT (ug/kg)

Legend

- □ 2,3,7,8-TCDD
- ◇ Total DDT
- ▲ Cesium-137

Location

May 1995, River Mile 3.1
TSI Location 228

Notes:

Total DDT represents the sum of the three 4,4'-isomers (whenever possible).

Nondetected values were incorporated into the sum as half the reported detection limit.

Nondetected concentrations of 2,3,7,8-TCDD were not reported at this coring location.

Depth (ft)

Cesium-137 Concentration (pCi/g)

Downcore Profile for 2,3,7,8-TCDD and Total DDT
(River Mile 3.1)
Lower Passaic River Restoration Project

Figure 4-5c

February 2006
Draft
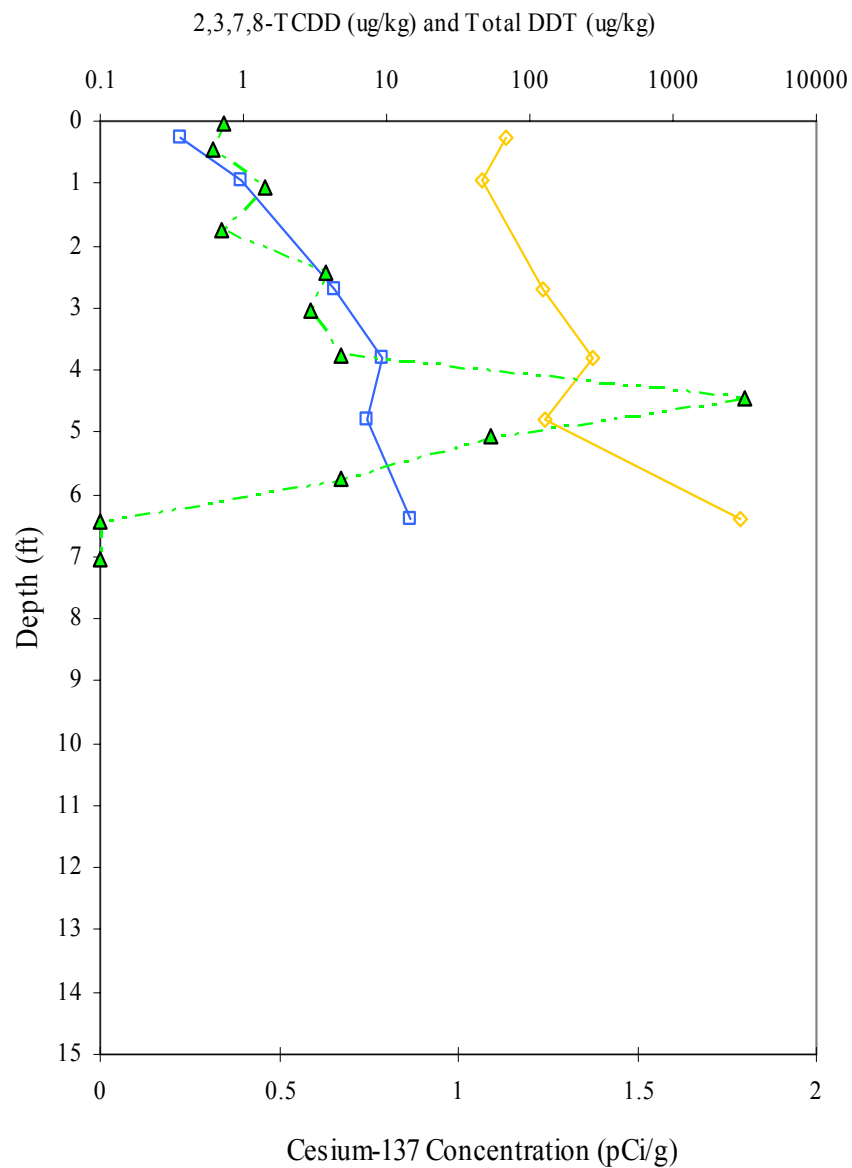
MALCOLM PIRNIE

2,3,7,8-TCDD (ug/kg) and Total DDT (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for 2,3,7,8-TCDD and Total DDT
(River Mile 3.1)
Lower Passaic River Restoration Project

Figure 4-5d

February 2006
Draft
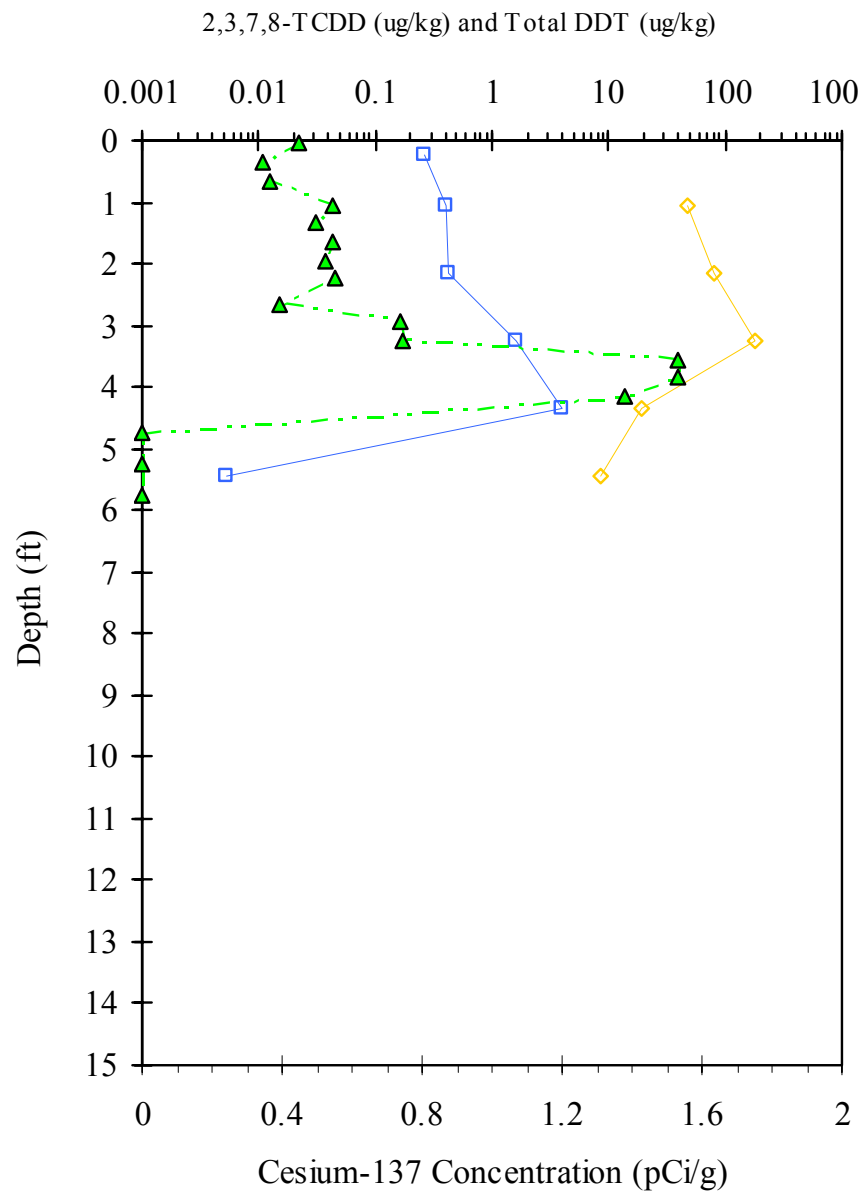
MALCOLM PIRNIE

2,3,7,8-TCDD (ug/kg) and Total DDT (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Downcore Profile for 2,3,7,8-TCDD and Total DDT
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-5e

February 2006
Draft
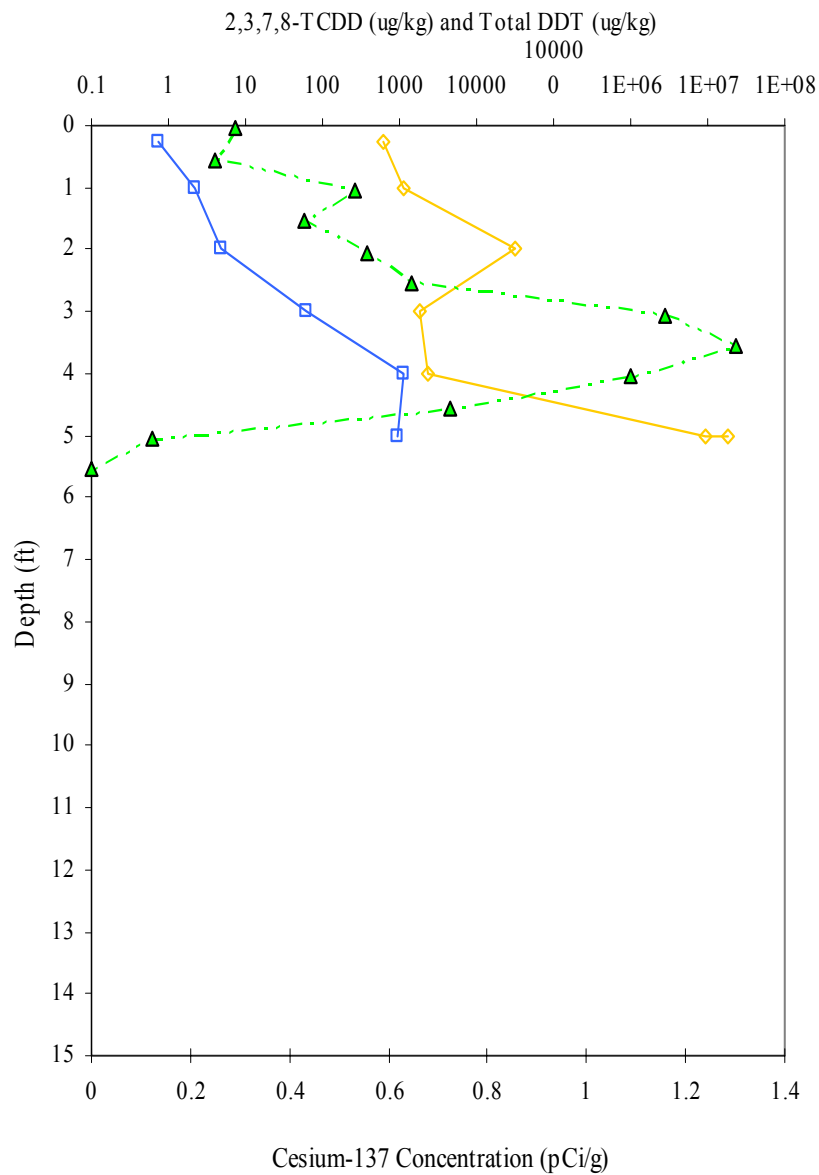
US Army Corps of Engineers®

MALCOLM PIRNIE

Downcore Profile for 2,3,7,8-TCDD and Total DDT
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-5f

February 2006
Draft
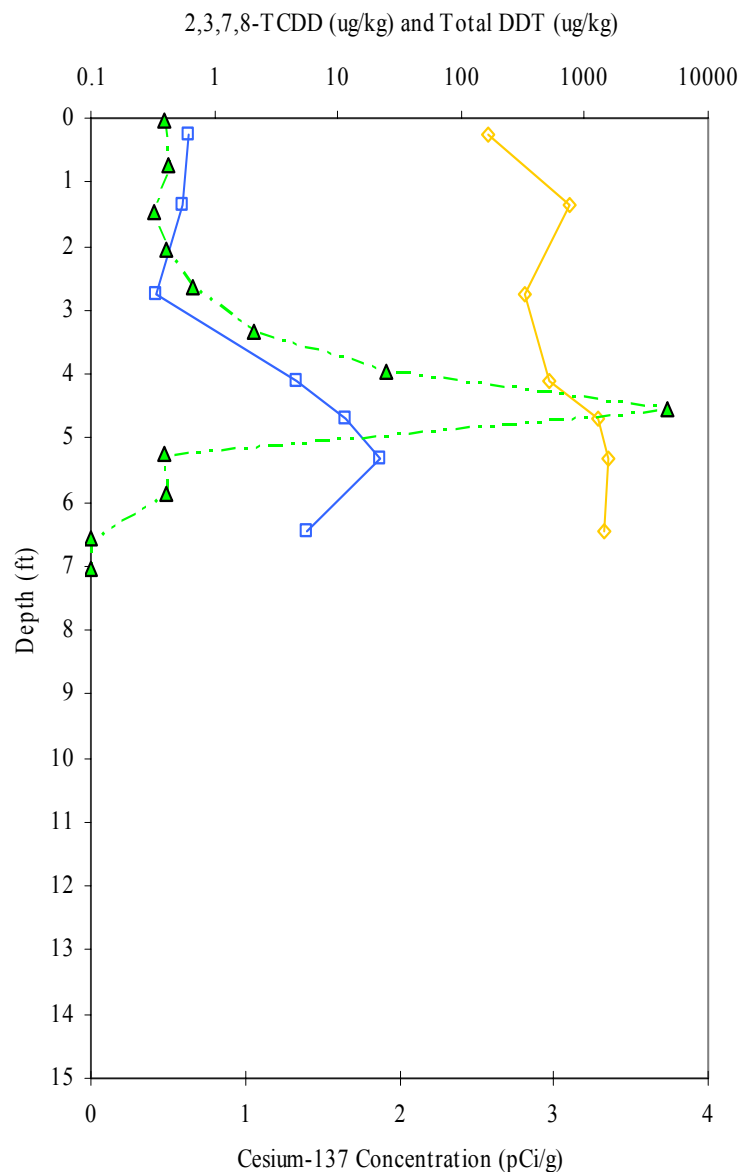
2,3,7,8-TCDD (ug/kg) and Total DDT (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Downcore Profile for 2,3,7,8-TCDD and Total DDT
(River Mile 3.6)
Lower Passaic River Restoration Project

Figure 4-5g

February 2006
Draft
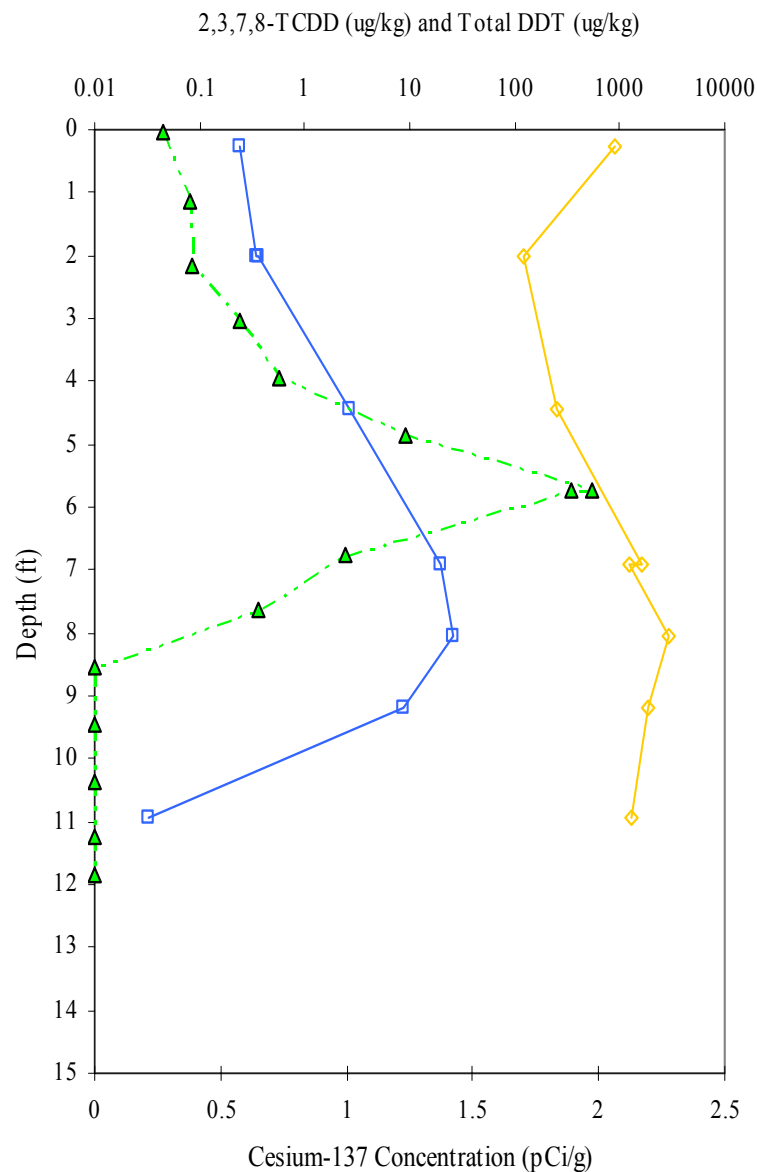
US Army Corps
of Engineers®

MALCOLM
PIRNIE

Downcore Profile for 2,3,7,8-TCDD and Total DDT
(River Mile 4.0)
Lower Passaic River Restoration Project

Figure 4-5h

February 2006
Draft
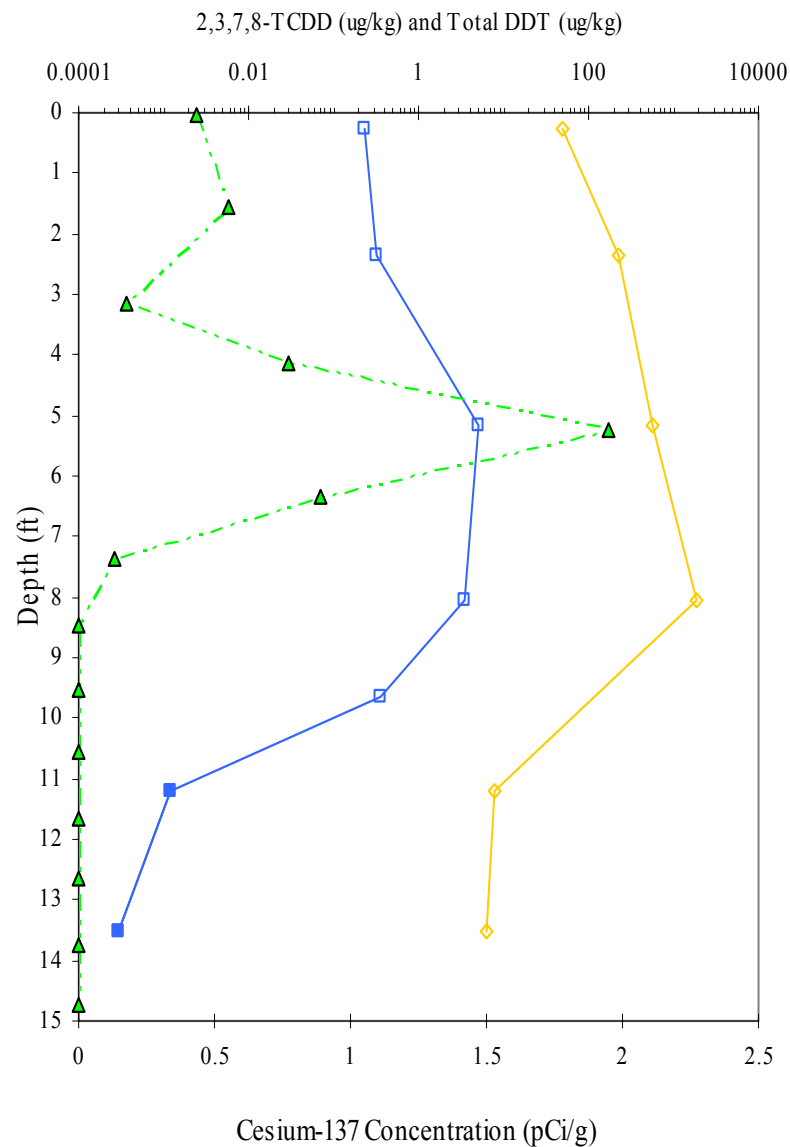
Legend

- 2,3,7,8-TCDD
- Total DDT
- 2,3,7,8-TCDD Nondetect
- Cesium-137

Location

May 1995, River Mile 4.5
TSI Location 248

Notes

Total DDT represents the sum of the three 4,4'-isomers (whenever possible).

Nondetected values were incorporated into the sum as half the reported detection limit.

Nondetected concentrations of 2,3,7,8-TCDD are plotted as half the reported detection limit.

Downcore Profile for 2,3,7,8-TCDD and Total DDT
(River Mile 4.5)
Lower Passaic River Restoration Project

Figure 4-5i

February 2006
Draft
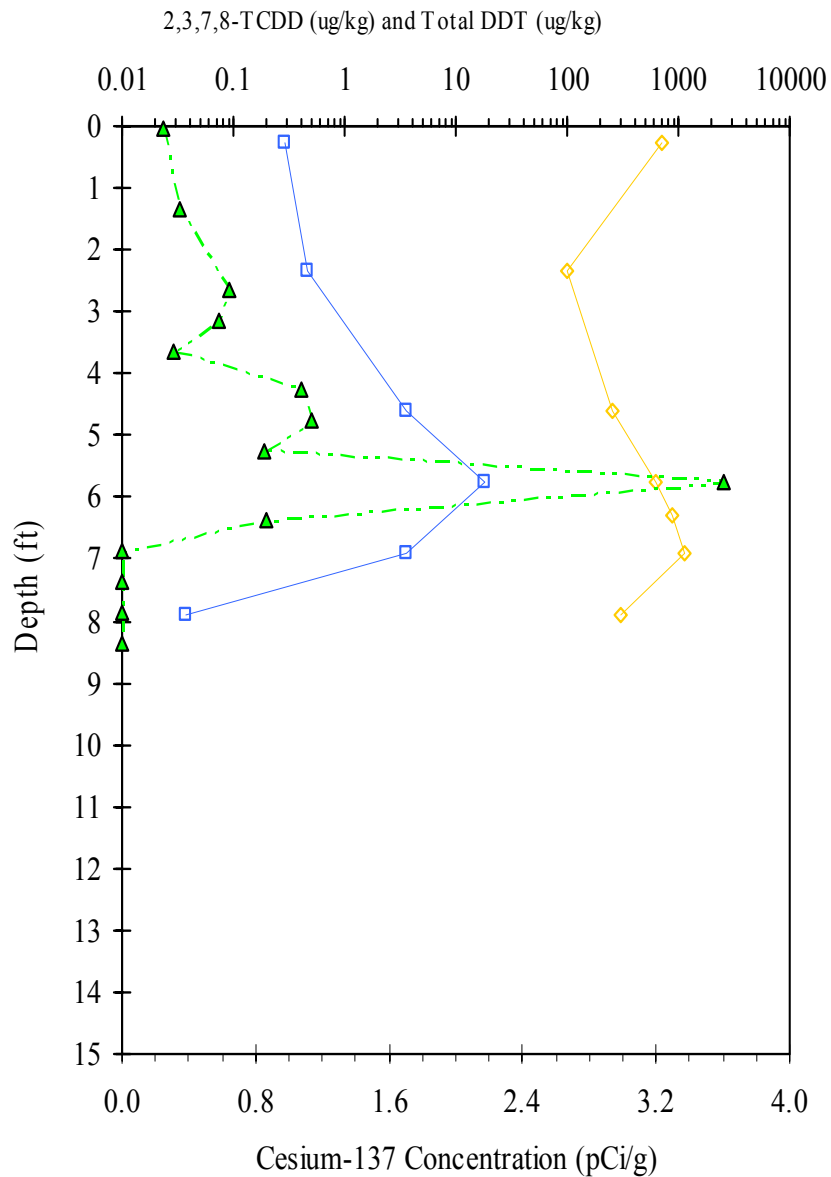
Downcore Profile for 2,3,7,8-TCDD and Total DDT
(River Mile 4.7)

Lower Passaic River Restoration Project

Figure 4-5j

February 2006
Draft
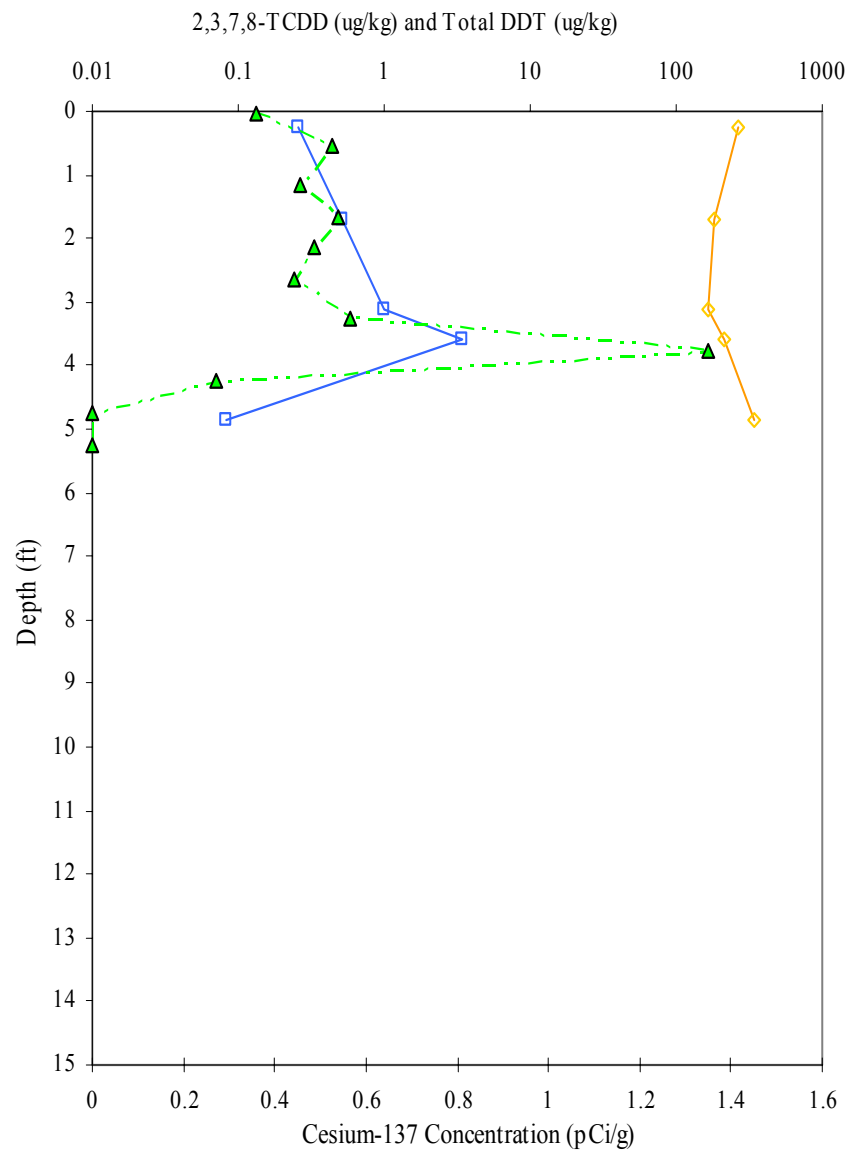
Downcore Profile for 2,3,7,8-TCDD and Total DDT
(River Mile 4.9)

Lower Passaic River Restoration Project

Figure 4-5k

February 2006
Draft
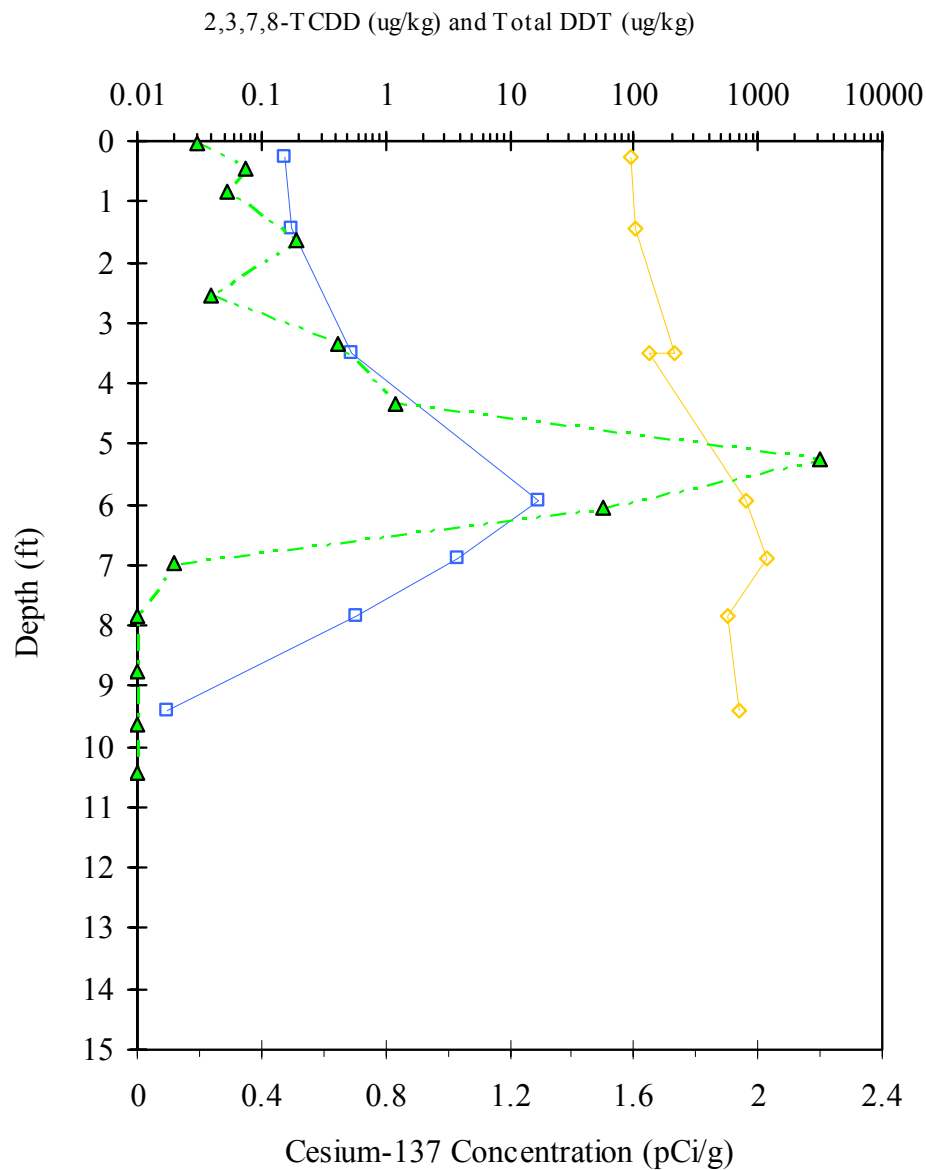
Downcore Profile for 2,3,7,8-TCDD and Total DDT
(River Mile 6.3)
Lower Passaic River Restoration Project

Figure 4-5l

February 2006
Draft

Legend

- 2,3,7,8-TCDD
- Total DDT
- Cesium-137

Location

June 1995, River Mile 6.4
TSI Location 296

Notes:

Total DDT represents the sum of the three 4,4'-isomers (whenever possible).

Nondetected values were incorporated into the sum as half the reported detection limit.

Nondetected concentrations of 2,3,7,8-TCDD were not reported at this coring location.

Downcore Profile for 2,3,7,8-TCDD and Total DDT (River Mile 6.4)

Lower Passaic River Restoration Project

Figure 4-5m

February 2006
Draft
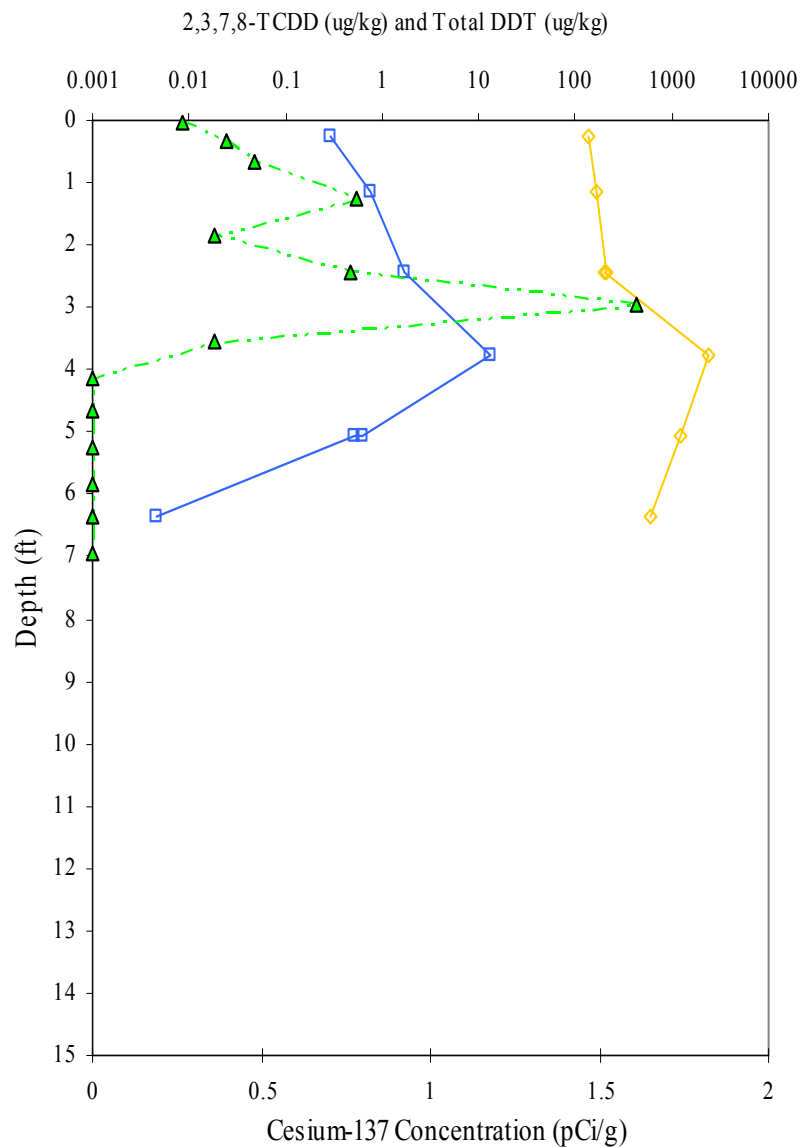
MALCOLM PIRNIE

2,3,7,8-TCDD (ug/kg) and Total DDT (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Location

June 1995, River Mile 6.5
TSI Location 275

Notes:

Total DDT represents the sum of the three 4,4'-isomers (whenever possible).

Nondetected values were incorporated into the sum as half the reported detection limit.

Nondetected concentrations of 2,3,7,8-TCDD were not reported at this coring location.

Downcore Profile for 2,3,7,8-TCDD and Total DDT
(River Mile 6.5)
Lower Passaic River Restoration Project

Figure 4-5n

February 2006
Draft

MALCOLM
PIRNIE

2,3,7,8-TCDD Concentration (ug/kg)

TCDD Ratio (unitless)

Year

Location

May 1995, River Mile 4.0
TSI Location 241

Notes

A ratio equal to 1 implies that The 2,3,7,8- TCDD concentration equals the concentration of the total TCDD. Note that some ratios plotted greater than 1, which shows an uncertainty in the analytical measurement. However, these deviations are typically within 25 percent, which is well within the expected analytical precision for the analysis.

2,3,7,8 TCDD and 2,3,7,8-Total TCDD /TCDD Ratio Comparison (River Mile 4.0)

Lower Passaic River Restoration Project

Figure 4-6a

February 2006
Draft

2,3,7,8 TCDD and 2,3,7,8-Total TCDD /TCDD Ratio Comparison (River Mile 6.3)

Lower Passaic River Restoration Project

Figure 4-6b

February 2006
Draft
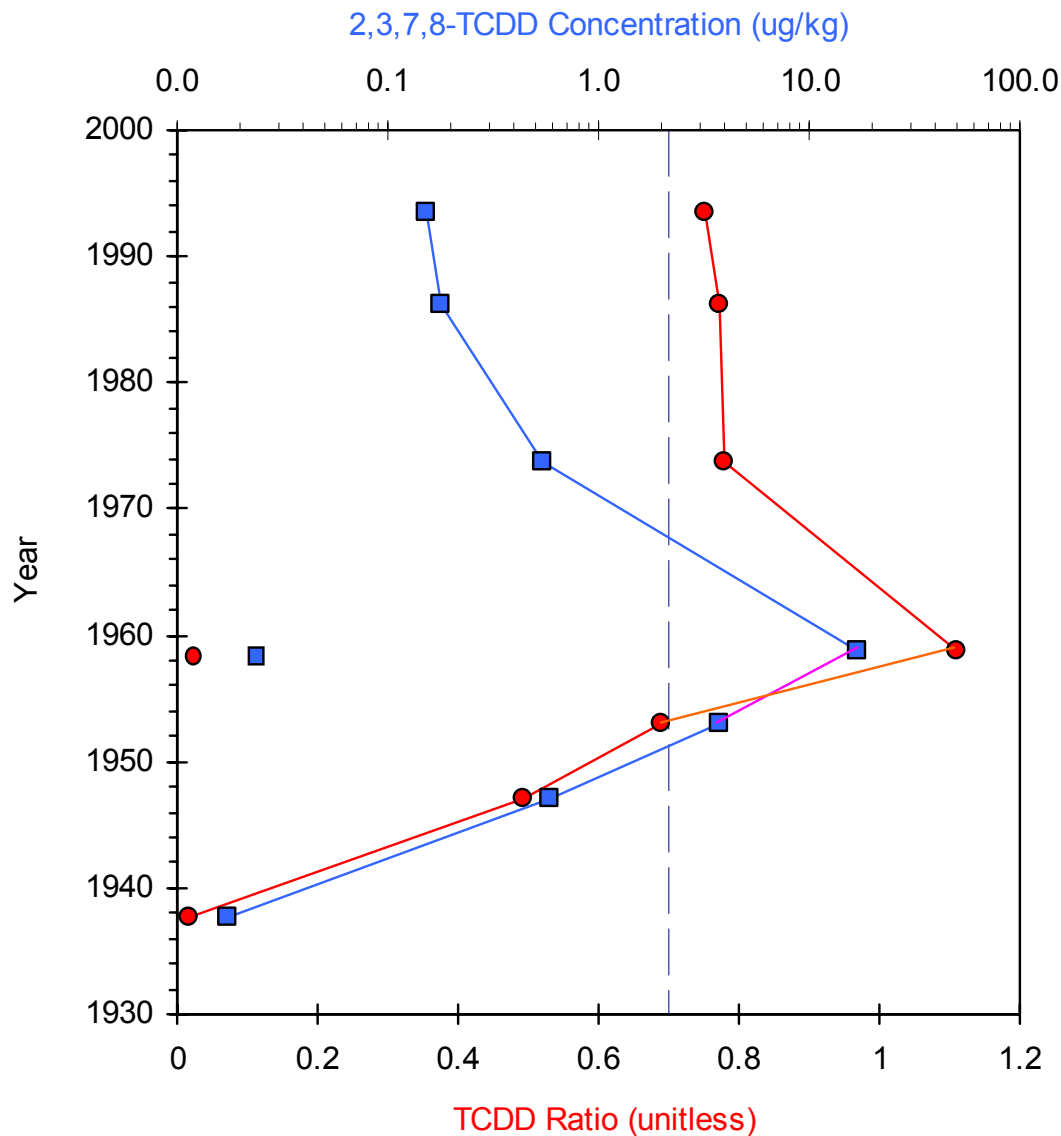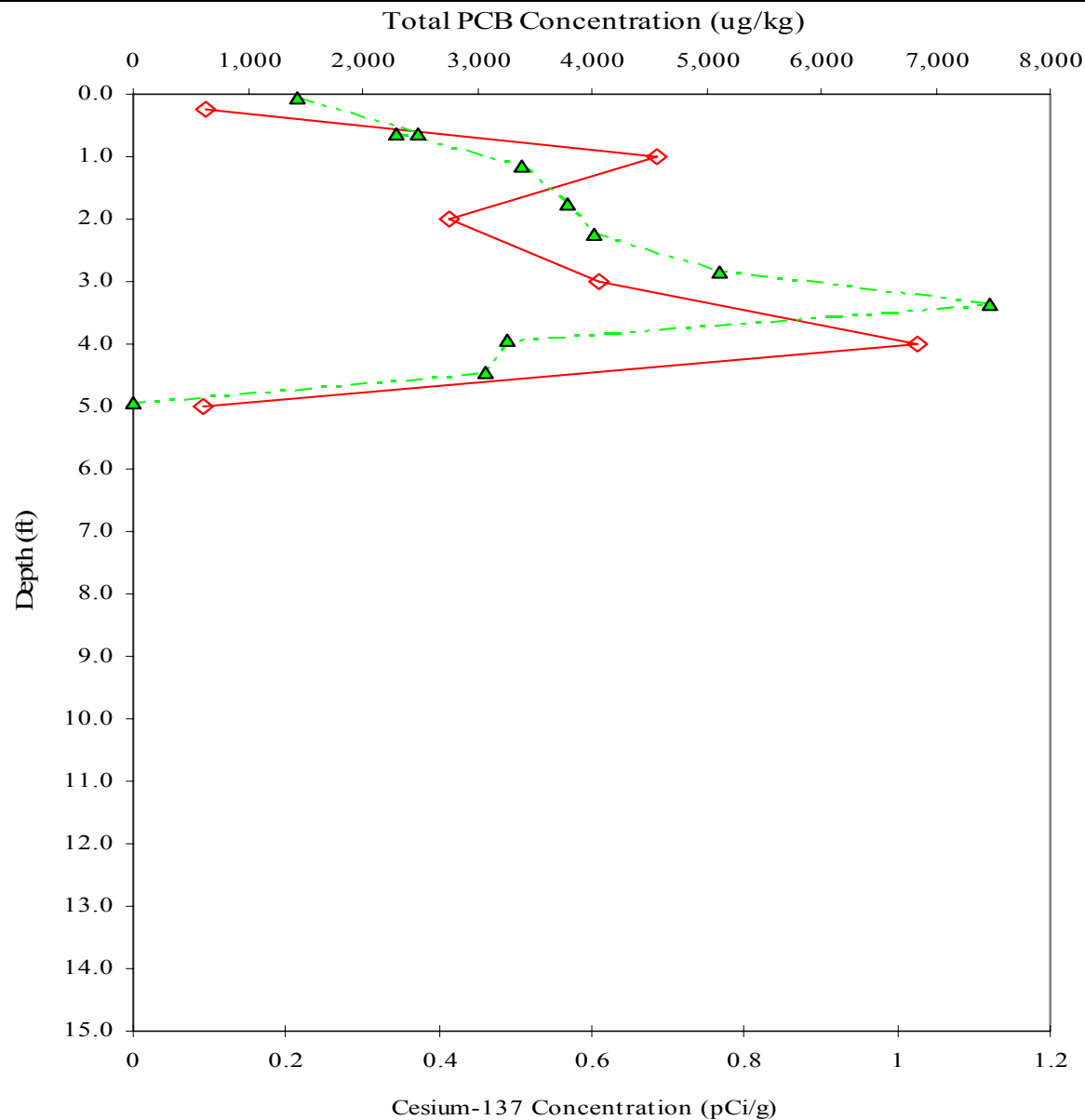
Legend

- 2,3,7,8-TCDD/TCDD

— 0.7 Ratio Reference Line (Chaky, 2003)

- 2,3,7,8-TCDD

Location

May 1995, River Mile 6.3
TSI Location 272

Notes

A ratio equal to 1 implies that The 2,3,7,8- TCDD concentration equals the concentration of the total TCDD. Note that some ratios plotted greater than 1, which shows an uncertainty in the analytical measurement. However, these deviations are typically within 25 percent, which is well within the expected analytical precision for the analysis.

Total PCB Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Legend

— Total PCB

--▲-- Cesium-137

Location

April 1995, River Mile 1.5
TSI Location 209

Notes

Total PCB represents
the sum of Aroclors
1248, 1254, and 1260.
Non-detected values
(lab qualifier containing
a U) are included in the
summation as zero if
one or more of the
three Aroclors are
detected. If all
Aroclors were
nondetect, the Total
PCB is half of the
highest reported
detection limit.

US Army Corps
of Engineers®

Downcore Profile for Total PCB
(River Mile 1.5)
Lower Passaic River Restoration Project

Figure 4-7a

February 2006
Draft
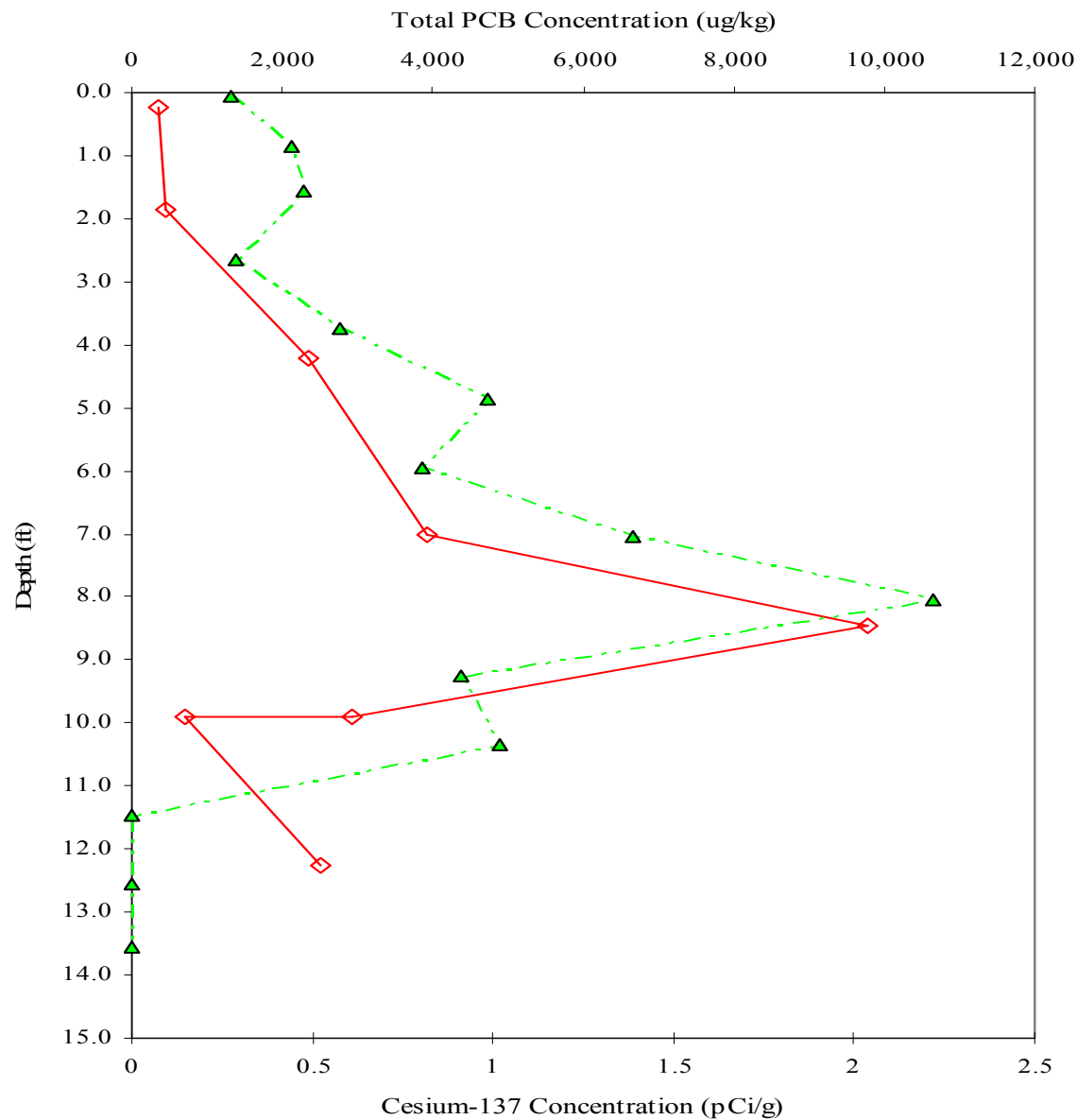
MALCOLM
PIRNIE

Total PCB Concentration (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Downcore Profile for Total PCB
(River Mile 2.7)
Lower Passaic River Restoration Project

Figure 4-7b

February 2006
Draft
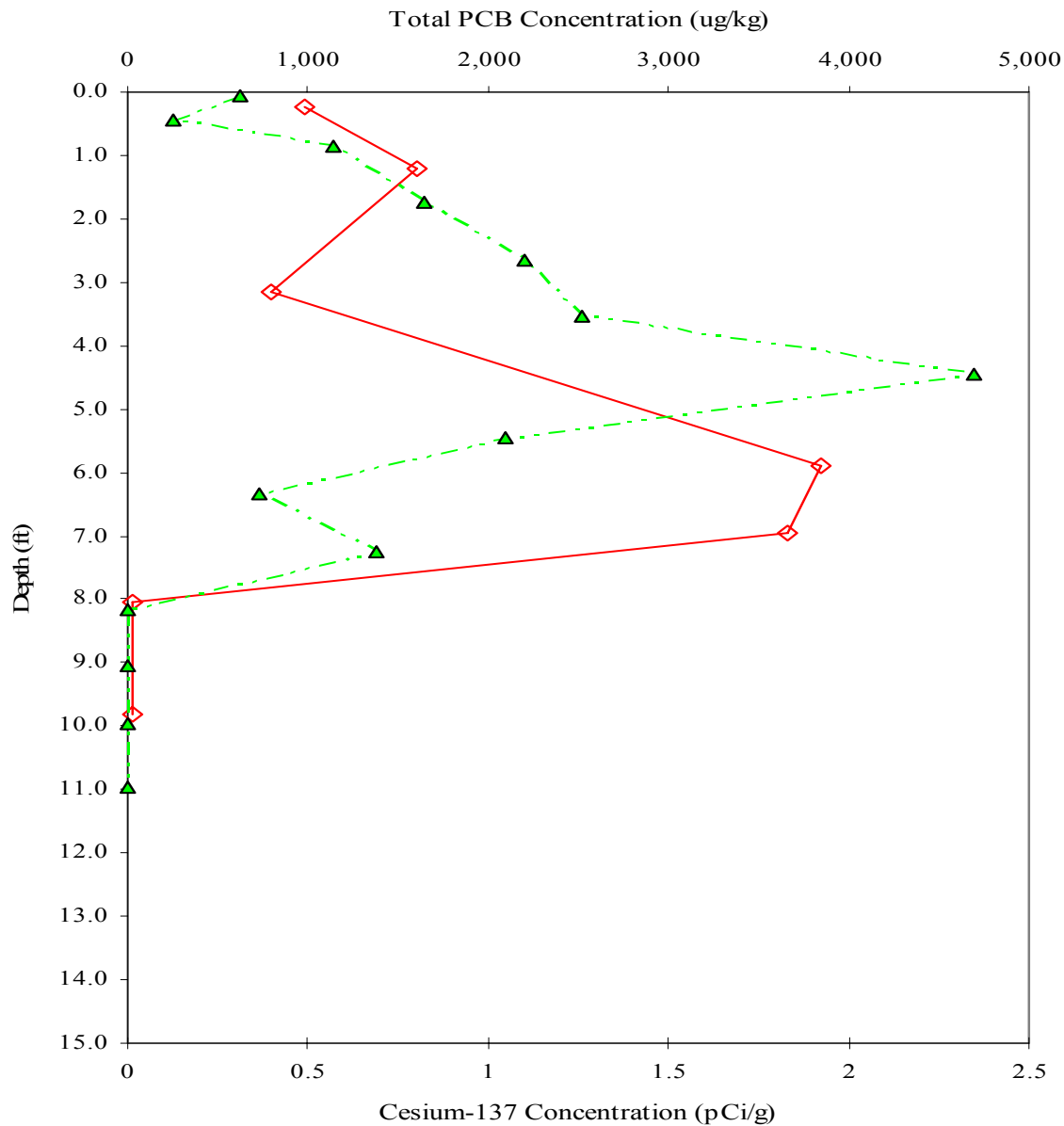
US Army Corps
of Engineers

MALCOLM
PIRNIE

Total PCB Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Total PCB
(River Mile 3.1)
Lower Passaic River Restoration Project

Figure 4-7c

February 2006
Draft
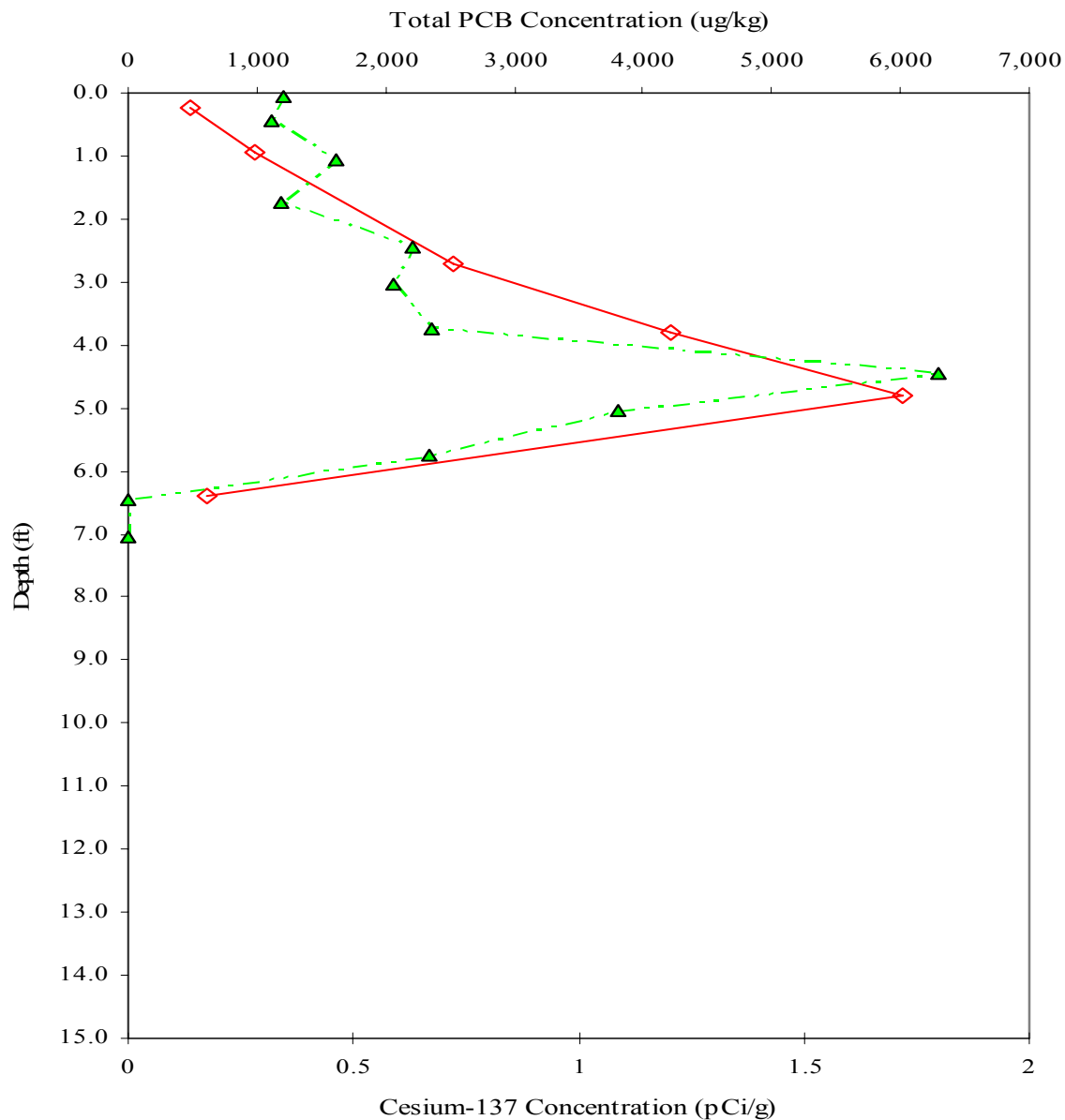
Total PCB Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Total PCB
(River Mile 3.1)
Lower Passaic River Restoration Project

US Army Corps
of Engineers®

Figure 4-7d

February 2006
Draft

MALCOLM
PIRNIE

Total PCB Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)
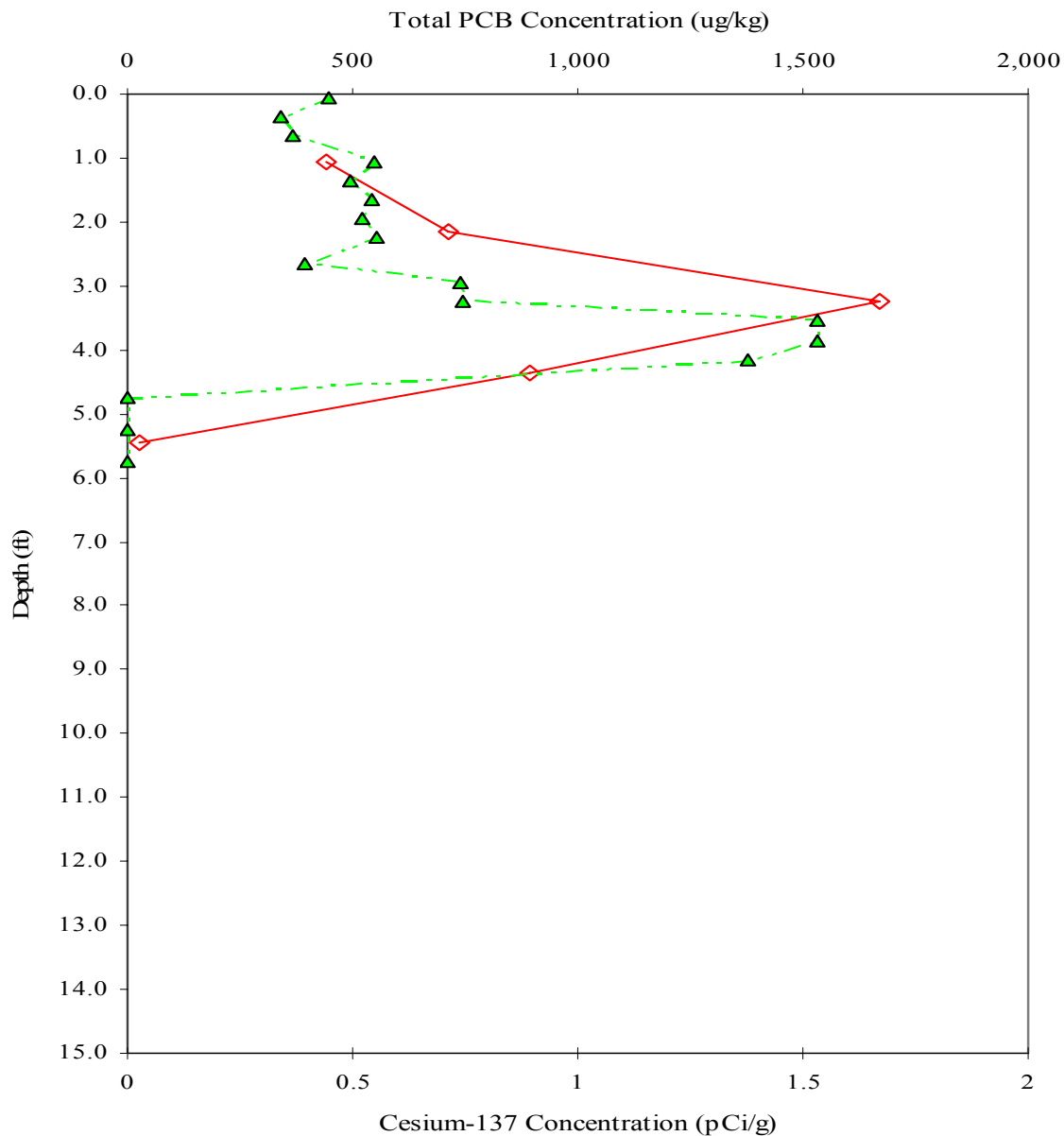
Location

May 1995, River Mile 3.3
TSI Location 232

Notes

Total PCB represents
the sum of Aroclors
1248, 1254, and 1260.
Non-detected values
(lab qualifier containing
a U) are included in the
summation as zero if
one or more of the
three Aroclors are
detected. If all
Aroclors were
nondetect, the Total
PCB is half of the
highest reported
detection limit.

Downcore Profile for Total PCB
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-7e

February 2006
Draft
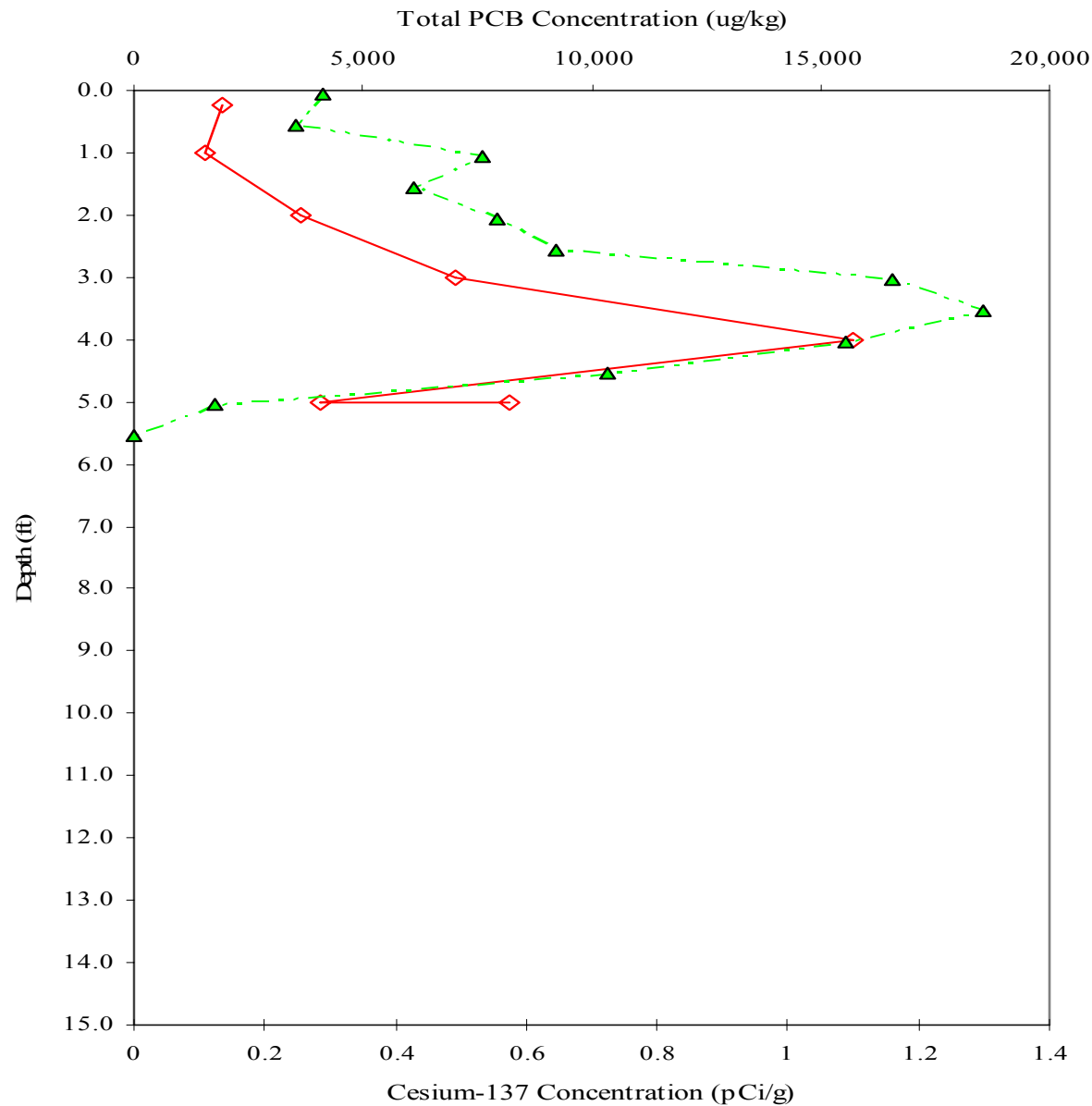
US Army Corps
of Engineers®

MALCOLM
PIRNIE

Total PCB Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Total PCB
(River Mile 3.3)
Lower Passaic River Restoration Project

US Army Corps
of Engineers®

Figure 4-7f

February 2006
Draft

MALCOLM
PIRNIE

Total PCB Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)
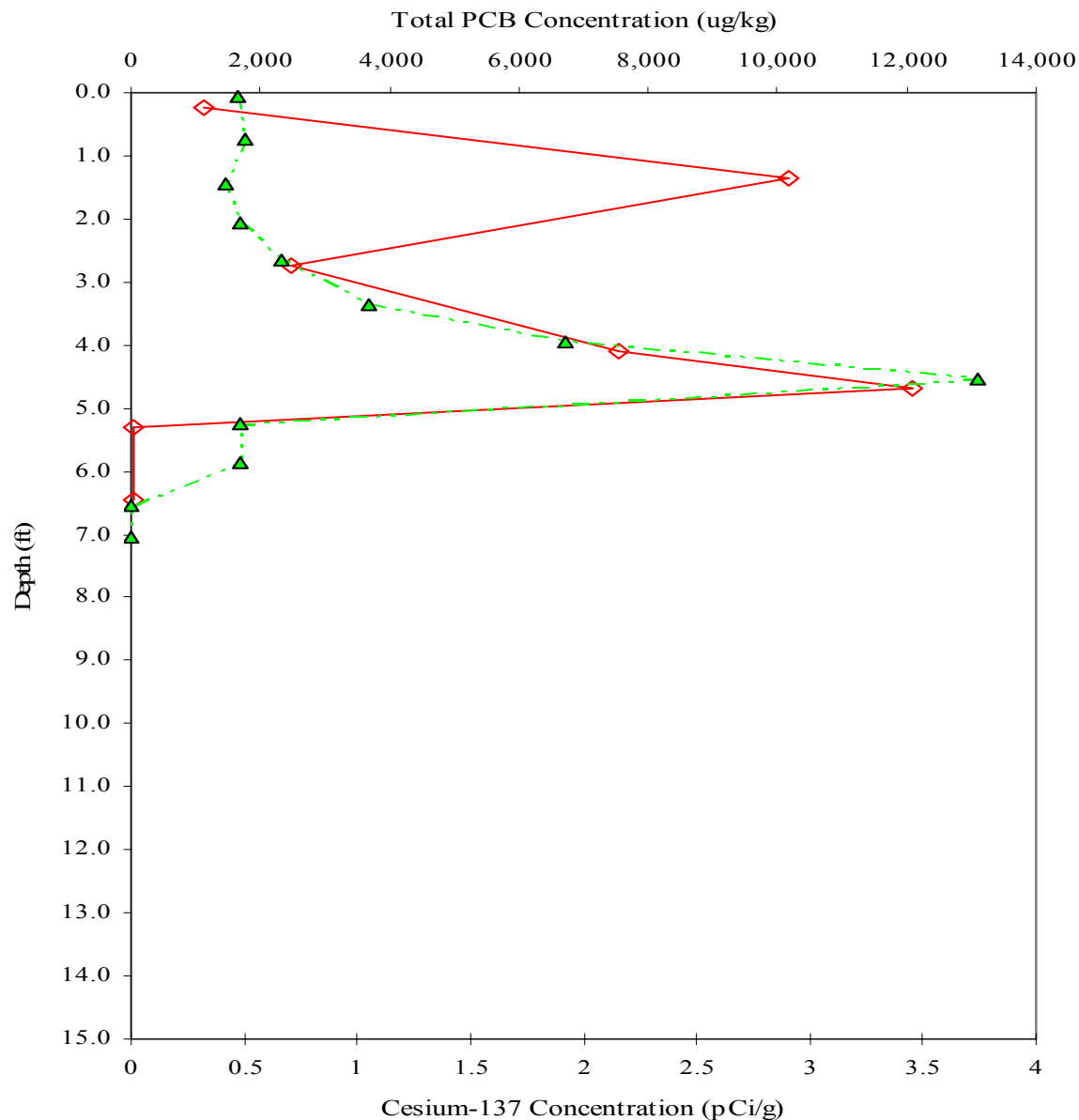
Location

May 1995, River Mile 3.6
TSI Location 235

Notes

Total PCB represents
the sum of Aroclors
1248, 1254, and 1260.
Non-detected values
(lab qualifier containing
a U) are included in the
summation as zero if
one or more of the
three Aroclors are
detected. If all
Aroclors were
nondetect, the Total
PCB is half of the
highest reported
detection limit.

Downcore Profile for Total PCB
(River Mile 3.6)
Lower Passaic River Restoration Project

US Army Corps
of Engineers®

Figure 4-7g

February 2006
Draft

MALCOLM
PIRNIE

Figure 4-7h

Downcore Profile for Total PCB
(River Mile 4.0)
Lower Passaic River Restoration Project

February 2006
Draft
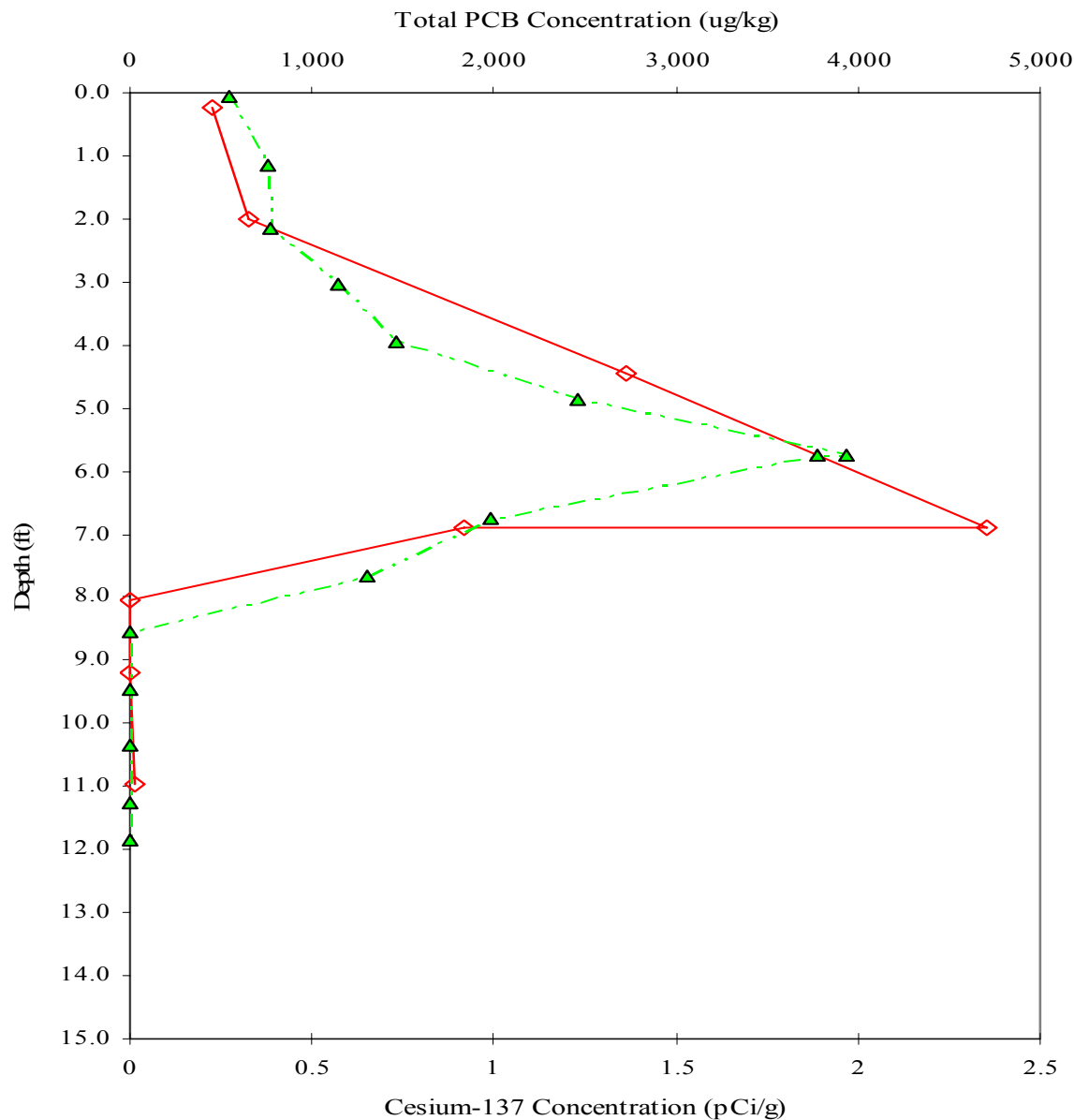
Legend

— Total PCB

-- Cesium-137

Location

May 1995, River Mile 4.0
TSI Location 241

Notes

Total PCB represents the sum of Aroclors 1248, 1254, and 1260. Non-detected values (lab qualifier containing a U) are included in the summation as zero if one or more of the three Aroclors are detected. If all Aroclors were nondetect, the Total PCB is half of the highest reported detection limit.

Total PCB Concentration (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Downcore Profile for Total PCB
(River Mile 4.5)
Lower Passaic River Restoration Project

US Army Corps
of Engineers®

noaa

Figure 4-7i

February 2006
Draft

MALCOLM
PIRNIE

Total PCB Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

US Army Corps
of Engineers

Downcore Profile for Total PCB
(River Mile 4.7)
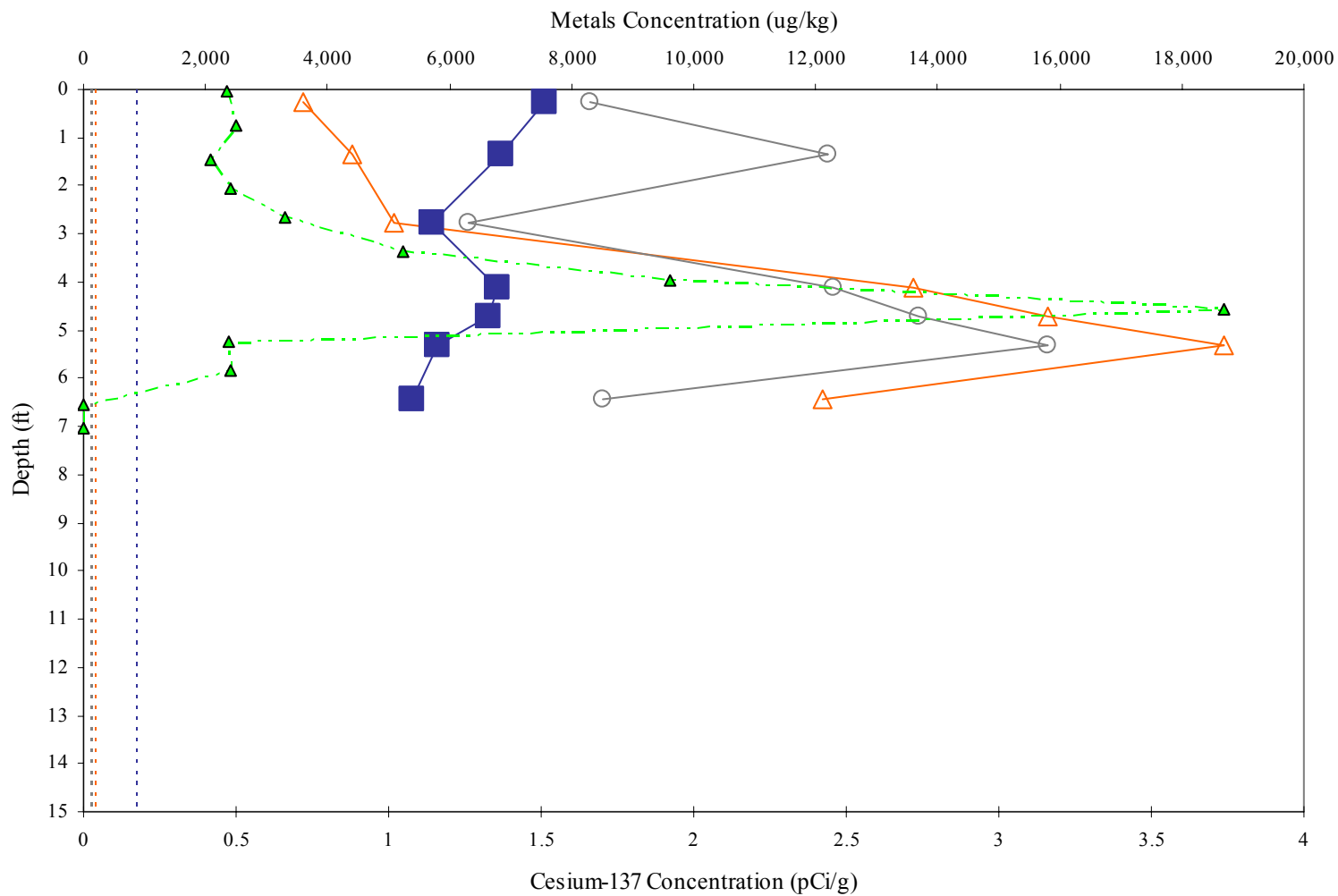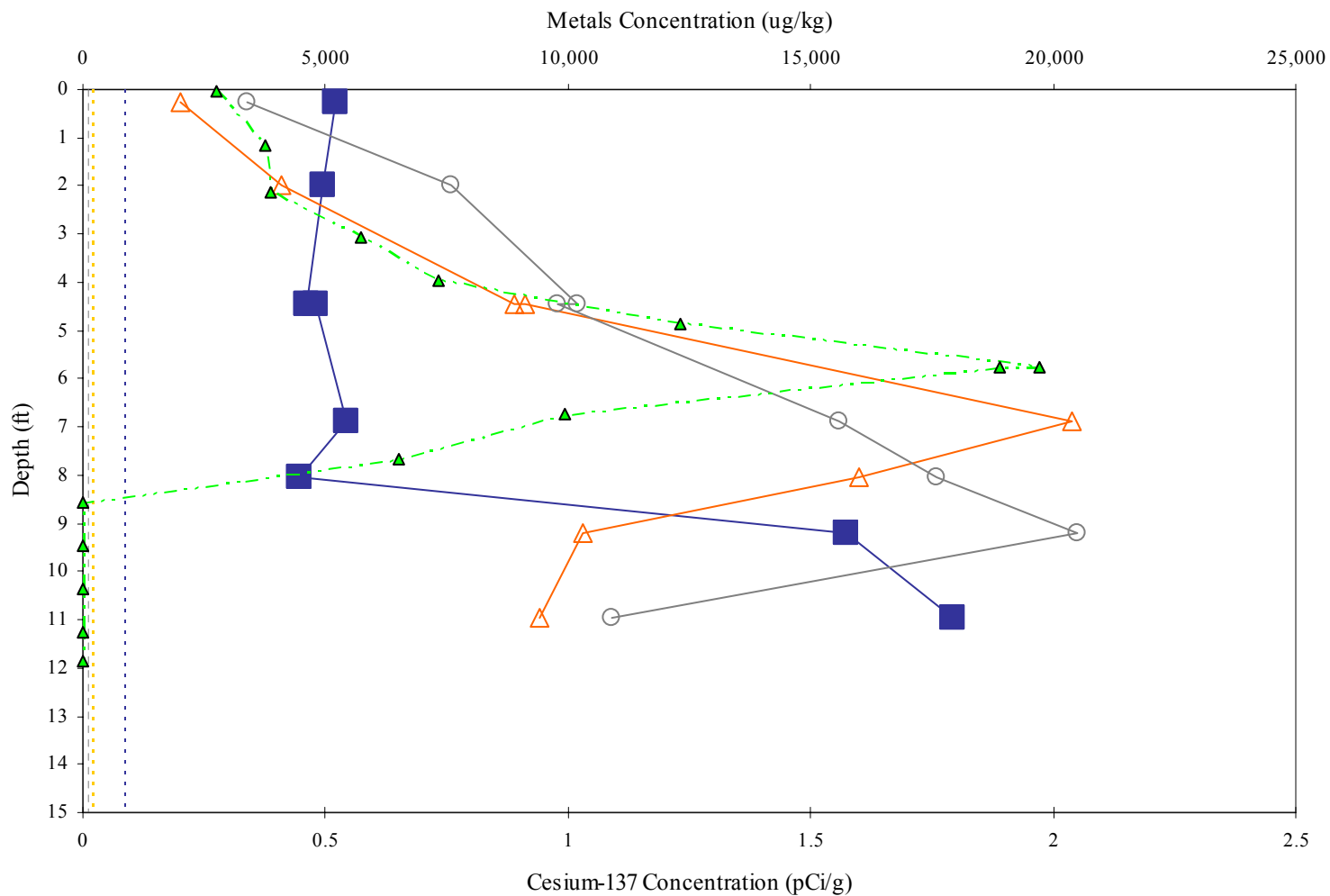Lower Passaic River Restoration Project

Figure 4-7j

February 2006
Draft

MALCOLM
PIRNIE

Downcore Profile for Total PCB
(River Mile 4.9)
Lower Passaic River Restoration Project

Figure 4-7k

February 2006
Draft
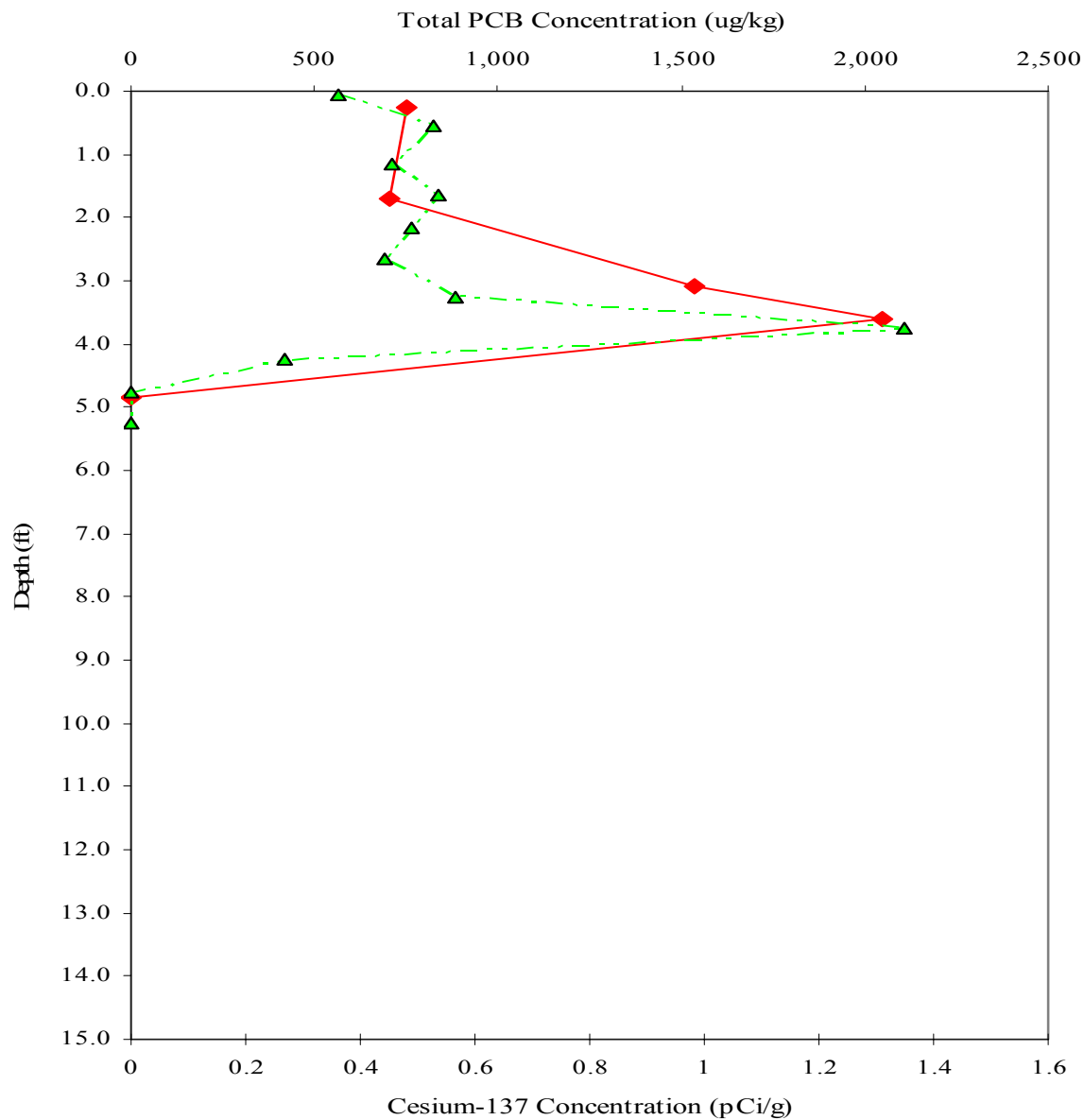
Legend

— Total PCB

-▲- Cesium-137

Location

May 1995, River Mile 4.9
TSI Location 253

Notes

Total PCB represents the sum of Aroclors 1248, 1254, and 1260. Non-detected values (lab qualifier containing a U) are included in the summation as zero if one or more of the three Aroclors are detected. If all Aroclors were nondetect, the Total PCB is half of the highest reported detection limit.

Total PCB Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Total PCB
(River Mile 6.3)
Lower Passaic River Restoration Project

US Army Corps
of Engineers

MALCOLM
PIRNIE

Figure 4-7I

February 2006
Draft

Total PCB Concentration (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Location

June 1995, River Mile 6.4
TSI Location 296

Notes

Total PCB represents
the sum of Aroclors
1248, 1254, and 1260.
Non-detected values
(lab qualifier containing
a U) are included in the
summation as zero if
one or more of the
three Aroclors are
detected. If all
Aroclors were
nondetect, the Total
PCB is half of the
highest reported
detection limit.

Downcore Profile for Total PCB
(River Mile 6.4)
Lower Passaic River Restoration Project

Figure 4-7m

February 2006
Draft
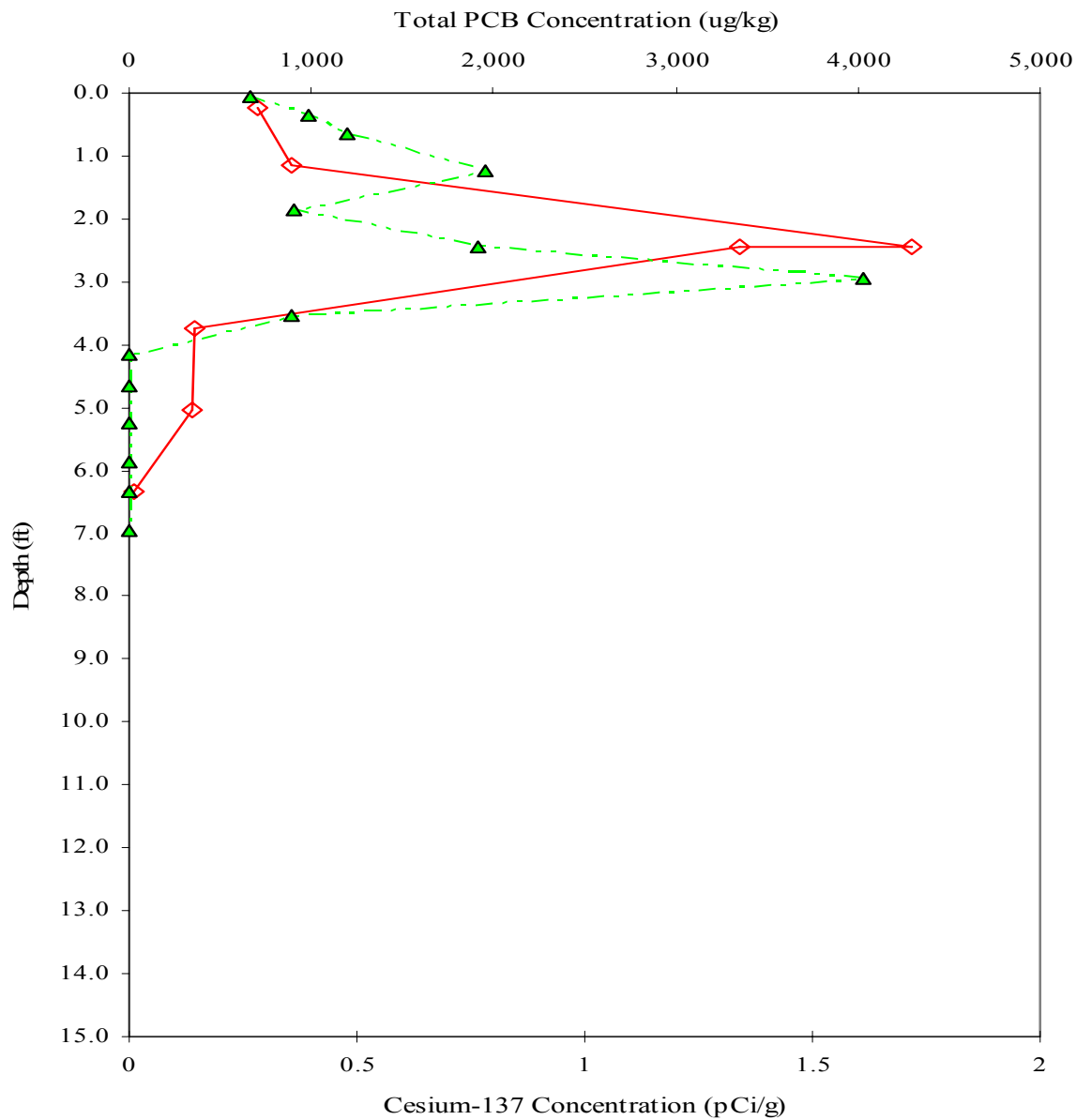
Total PCB Concentration (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Downcore Profile for Total PCB
(River Mile 6.5)
Lower Passaic River Restoration Project

Figure 4-7n

February 2006
Draft

US Army Corps
of Engineers

MALCOLM
PIRNIE
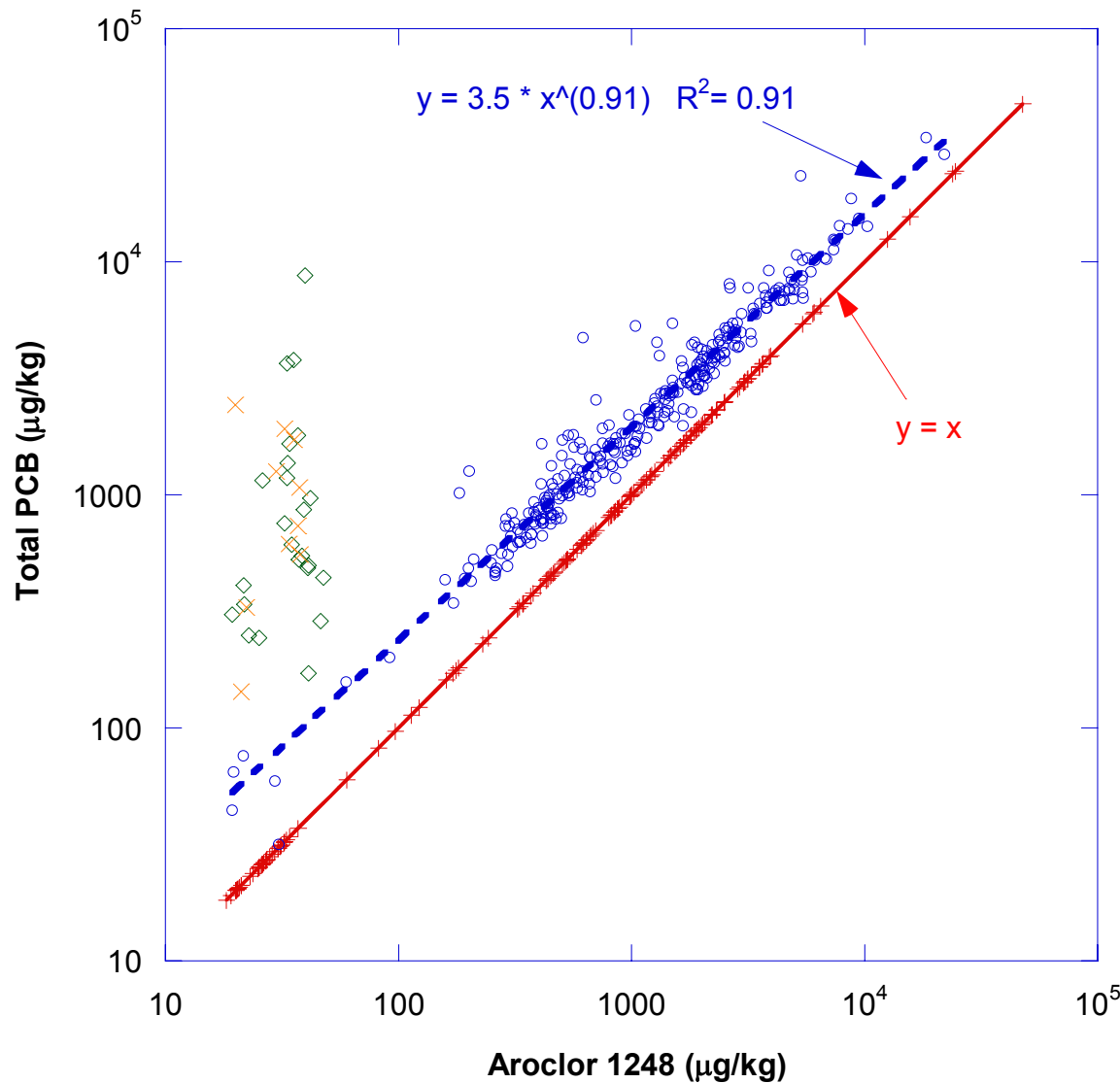
Legend

+ Total PCB = Aroclor 1248

○ Total PCB = Aroclor 1248 +
  Aroclor 1254 + Aroclor 1260

◇ High Total PCB,
  Nondetect Aroclor 1248

✕ High Total PCB,
  Low Aroclor 1248

Location
River Mile 1 to River Mile 7

Note:
Nondetect results for
Aroclor 1248 set at ½
the detection limit.

Plot annotations:
$y = 3.5 * x^{(0.91)}$ $R^2 = 0.91$
$y = x$

Y-axis: Total PCB (μg/kg)
X-axis: Aroclor 1248 (μg/kg)

Aroclor 1248 and Total PCB Concentration Correlation

Lower Passaic River Restoration Project

Figure 4-8

February 2006
Draft
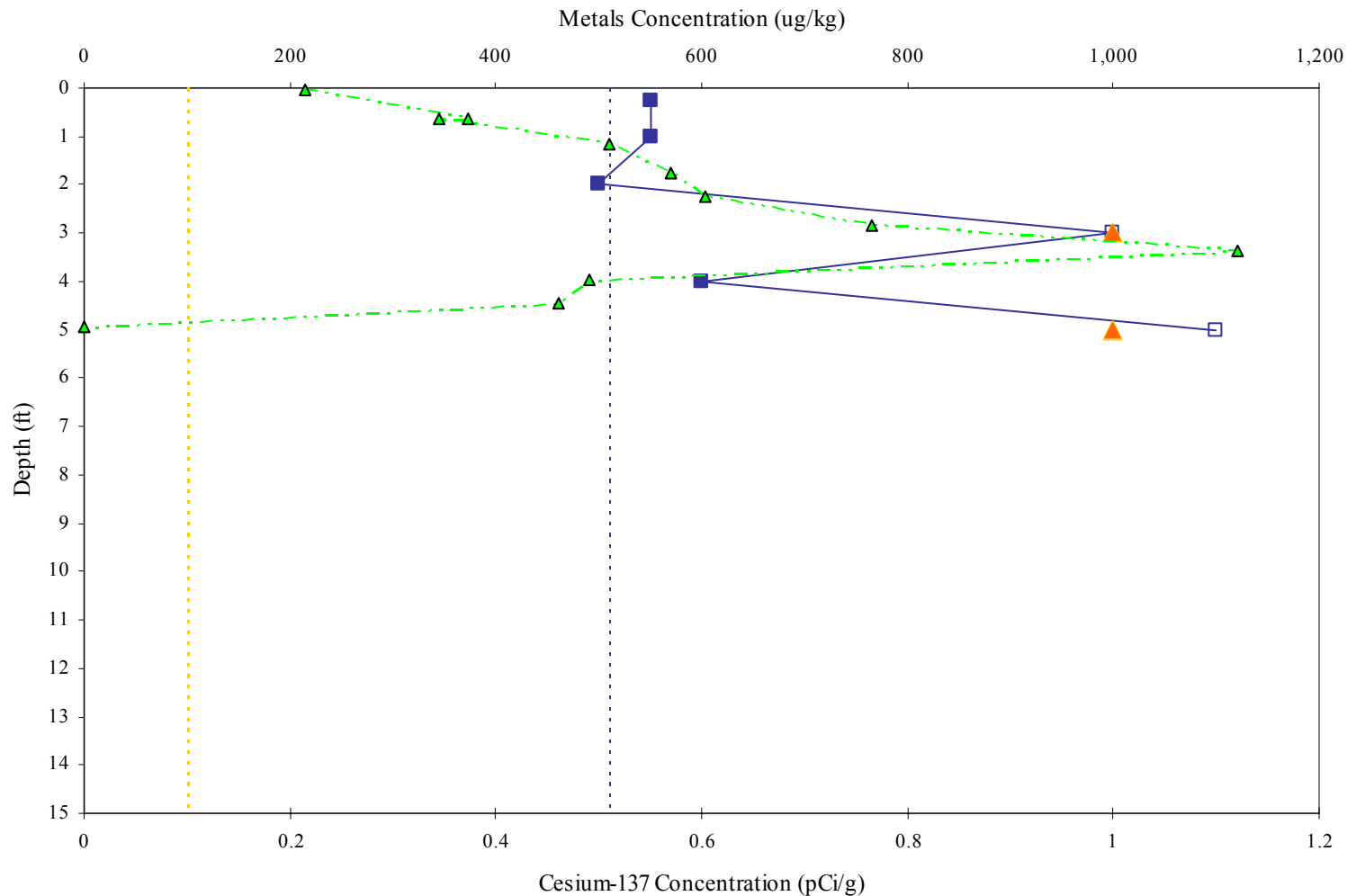
MALCOLM PIRNIE

Downcore Profile for Beryllium and Thallium
(River Mile 1.5)
Lower Passaic River Restoration Project

Figure 4-9a

February 2006
Draft
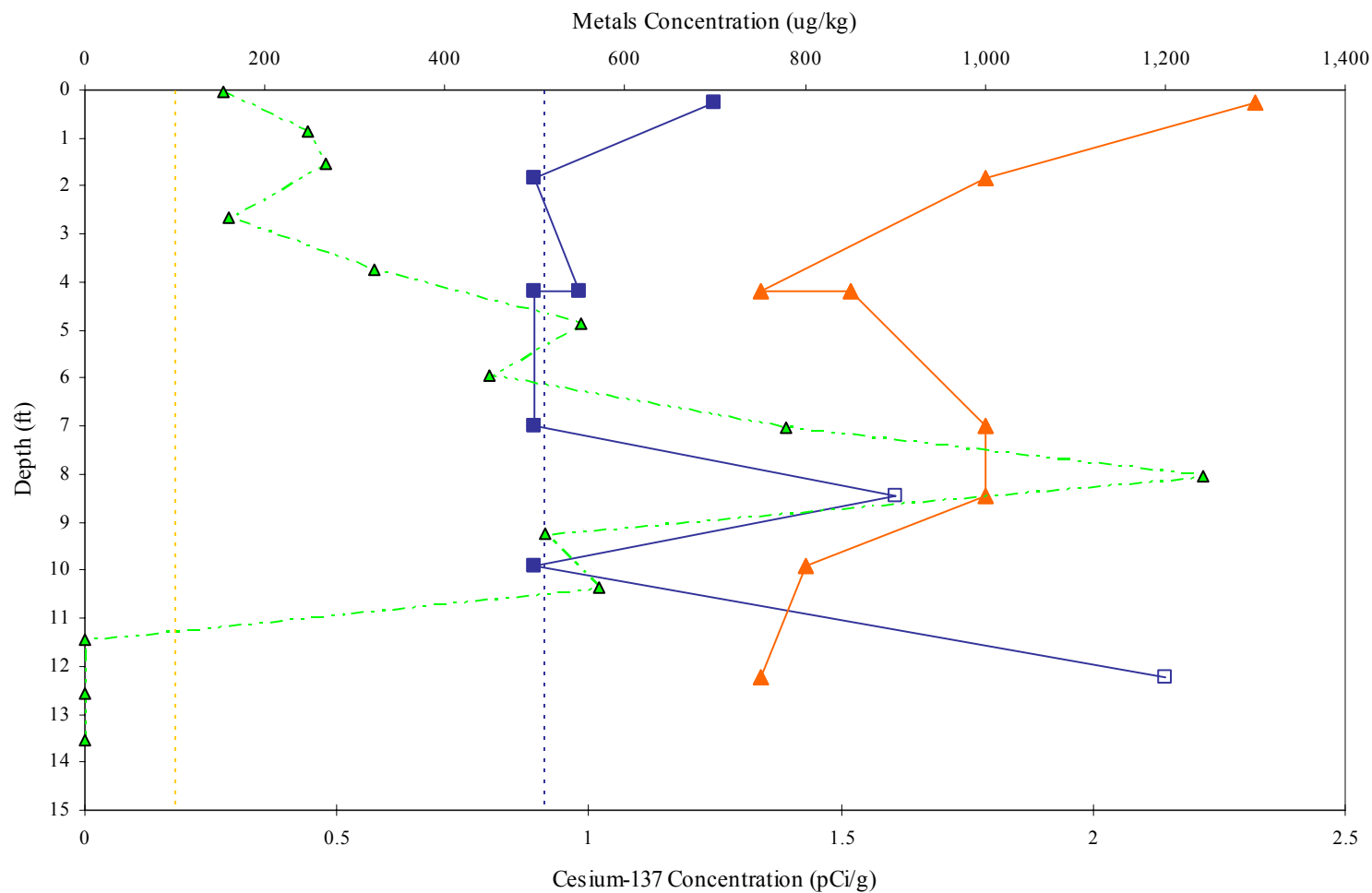
Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Beryllium and Thallium
(River Mile 2.7)
Lower Passaic River Restoration Project

Figure 4-9b

February 2006
Draft
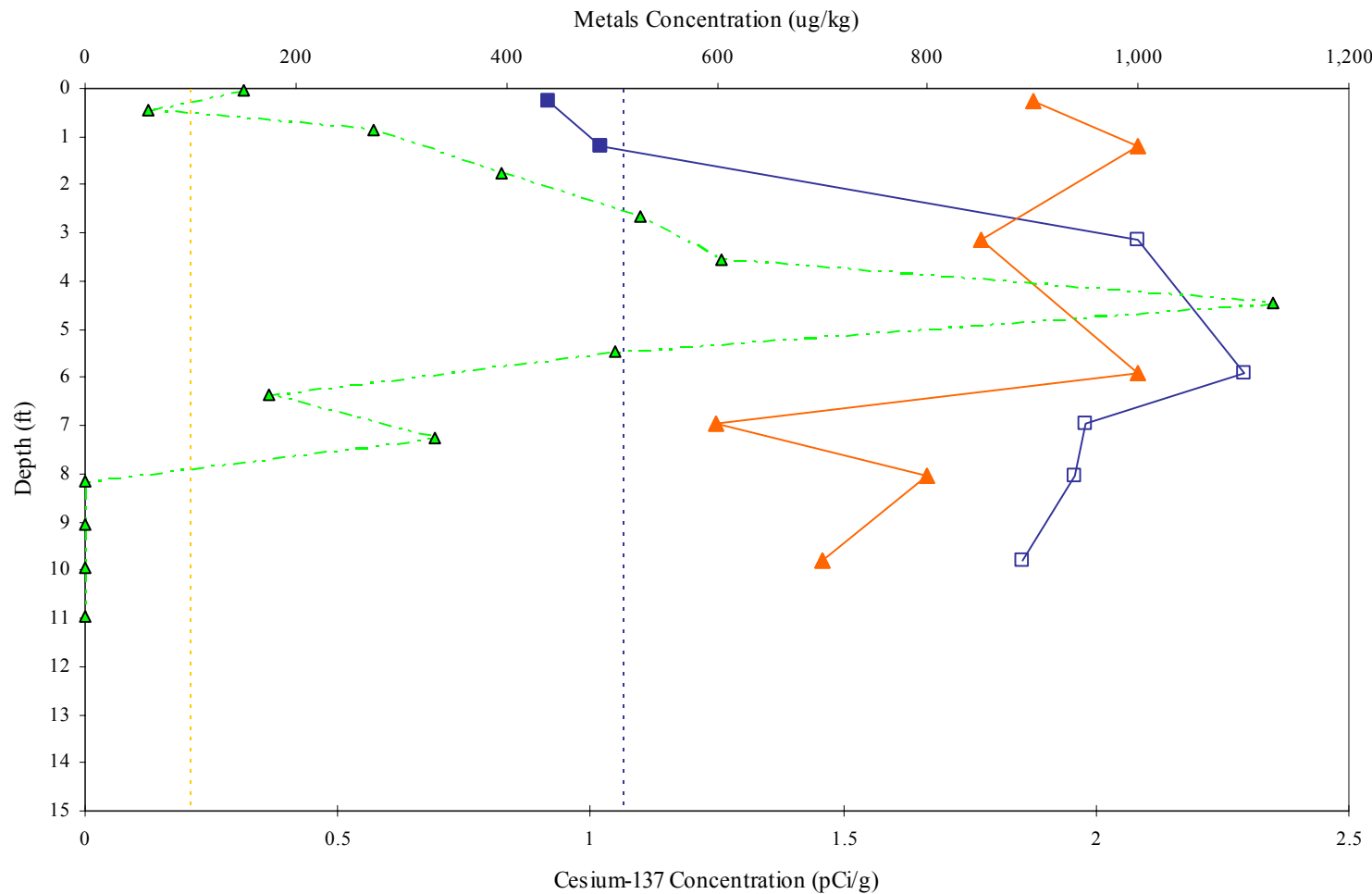
MALCOLM PIRNIE

Legend

Beryllium Detect
Beryllium Nondetect
Thallium Detect
Thallium Nondetect
Beryllium Background
Thallium Background
Cesium-137

Location

May 1995, River Mile 3.1
TSI Location 228

Notes

Metals background concentrations were taken
from Sanders, P.F., May 2003. "Ambient Levels
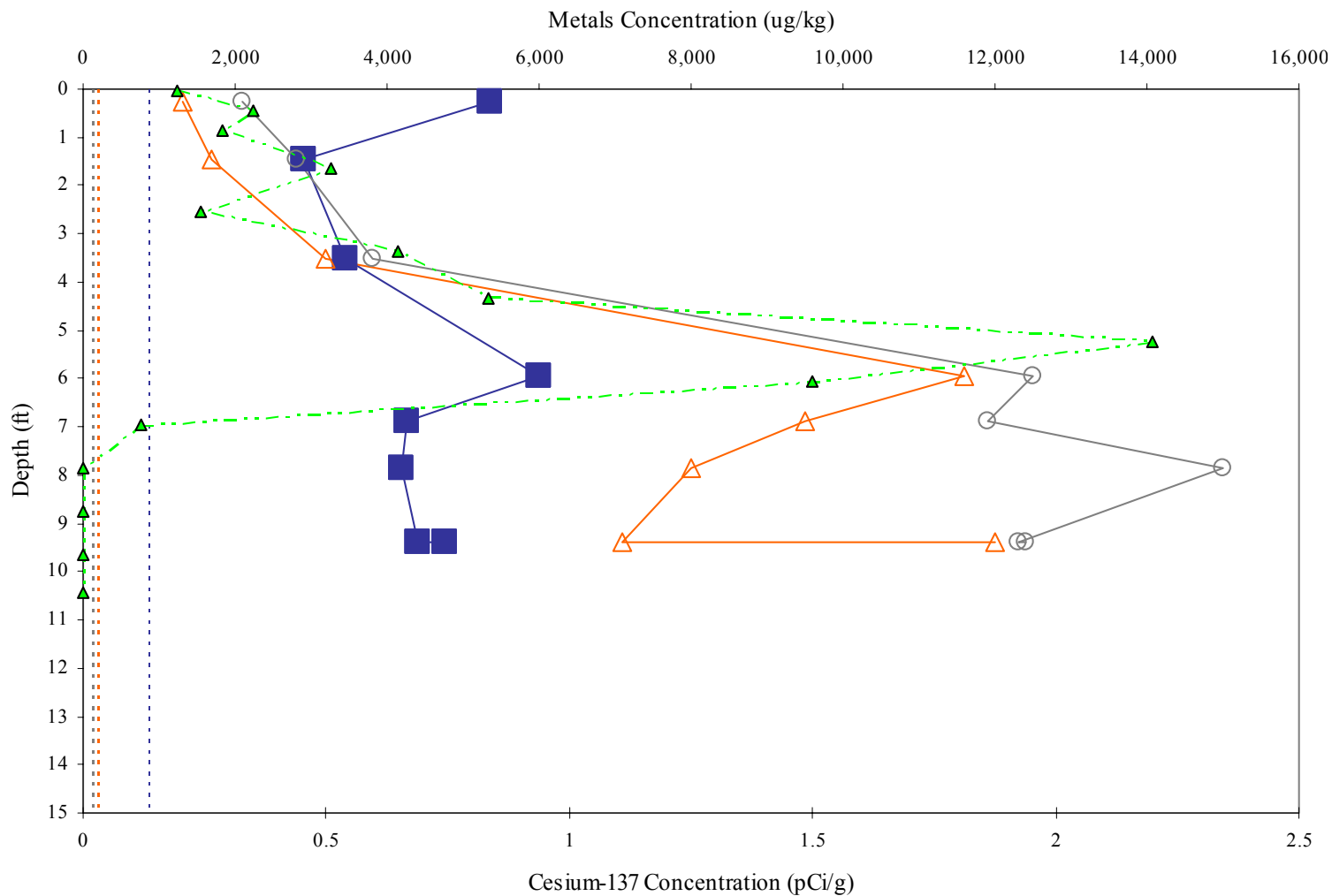of Metals in New Jersey Soils."
Available online: http://www.state.nj.us/dep/
dsr/research/ambient-levels-metal.pdf

Downcore Profile for Beryllium and Thallium
(River Mile 3.1)
Lower Passaic River Restoration Project

Figure 4-9c

February 2006
Draft
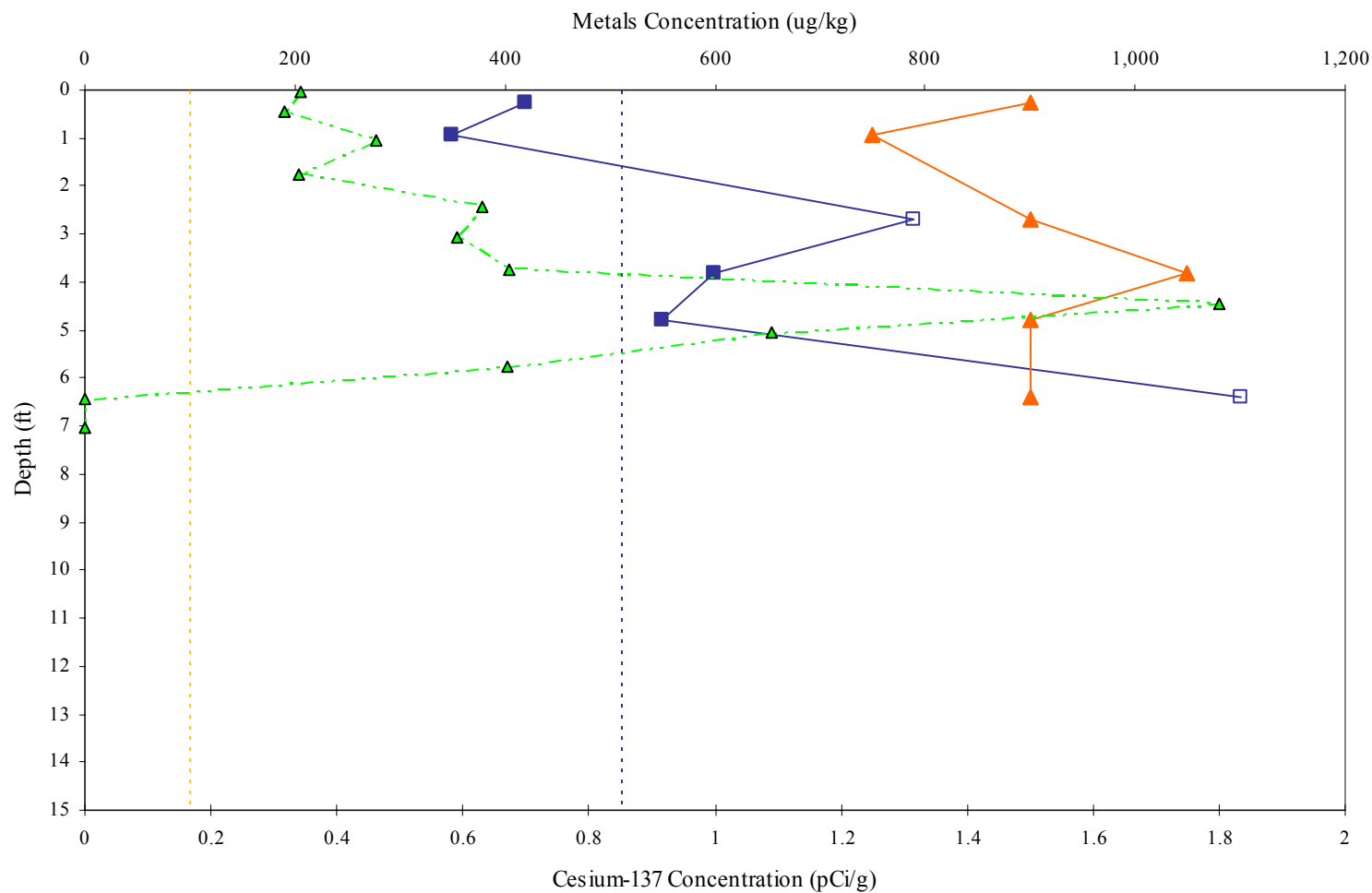
Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Legend

- Beryllium Detect
- Beryllium Nondetect
- Thallium Detect
- Thallium Nondetect
- Beryllium Background
- Thallium Background
- Cesium-137

Location

May 1995, River Mile 3.1
TSI Location 230

Notes

Metals background concentrations were taken from Sanders, P.F., May 2003. "Ambient Levels of Metals in New Jersey Soils."
Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Beryllium and Thallium
(River Mile 3.1)
Lower Passaic River Restoration Project

Figure 4-9d

February 2006
Draft
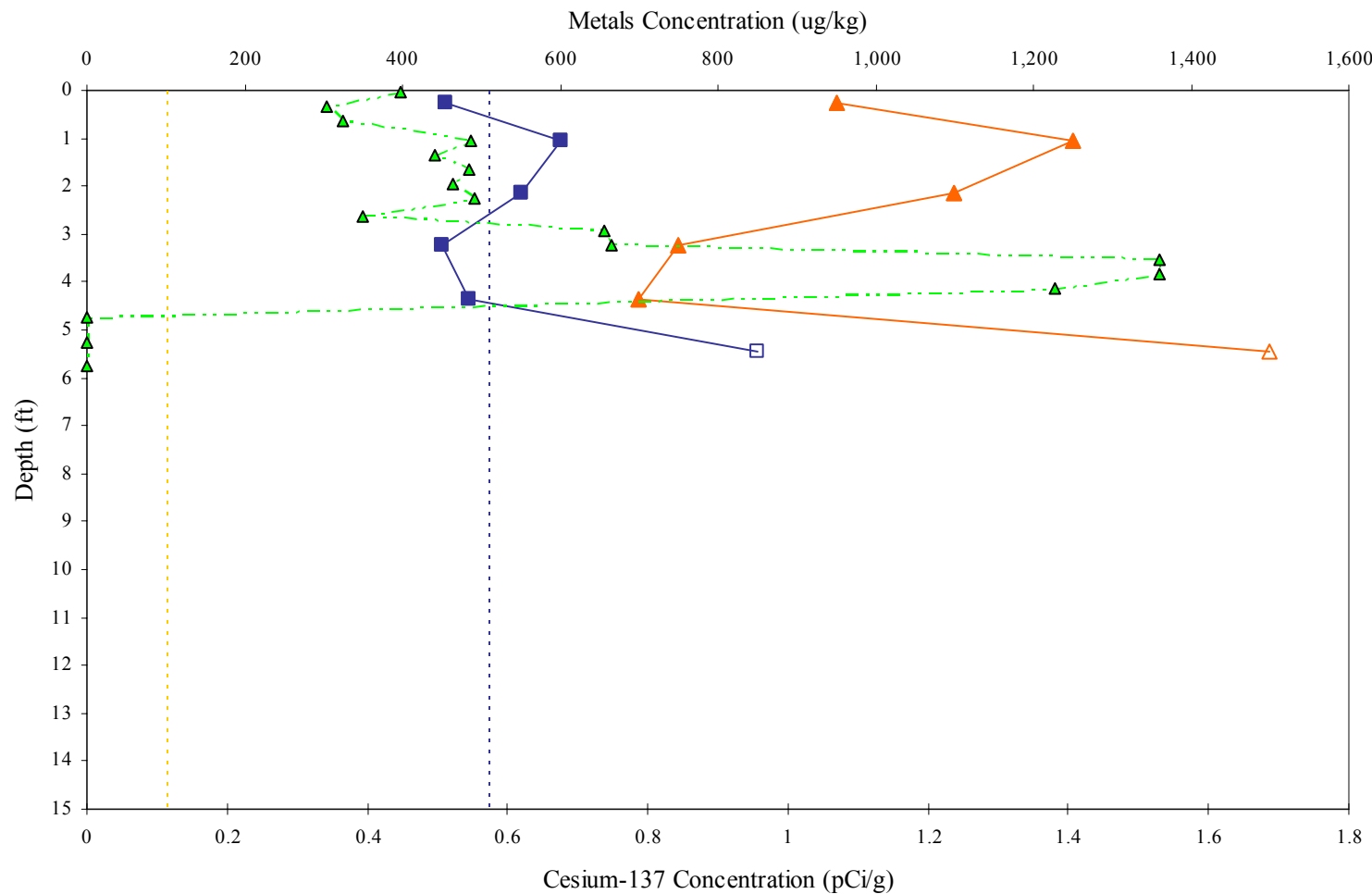
US Army Corps of Engineers®

MALCOLM PIRNIE

Legend

- Beryllium Detect
- Beryllium Nondetect
- Thallium Detect
- Thallium Nondetect
- Beryllium Background
- Thallium Background
- Cesium-137

Location

May 1995, River Mile 3.3
TSI Location 232

Notes

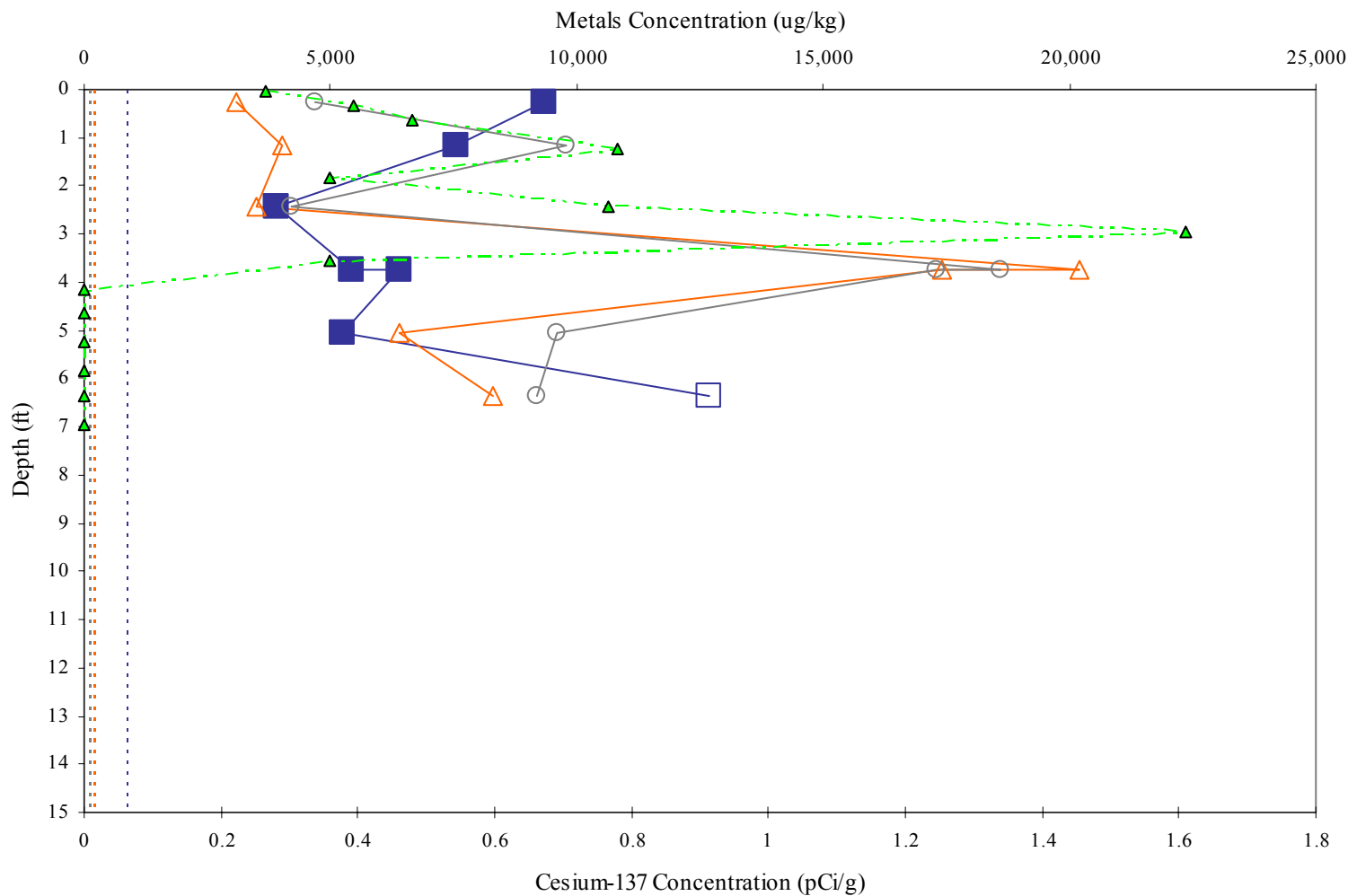Metals background concentrations were taken from Sanders, P.F., May 2003. "Ambient Levels of Metals in New Jersey Soils." Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Beryllium and Thallium
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-9e

February 2006
Draft
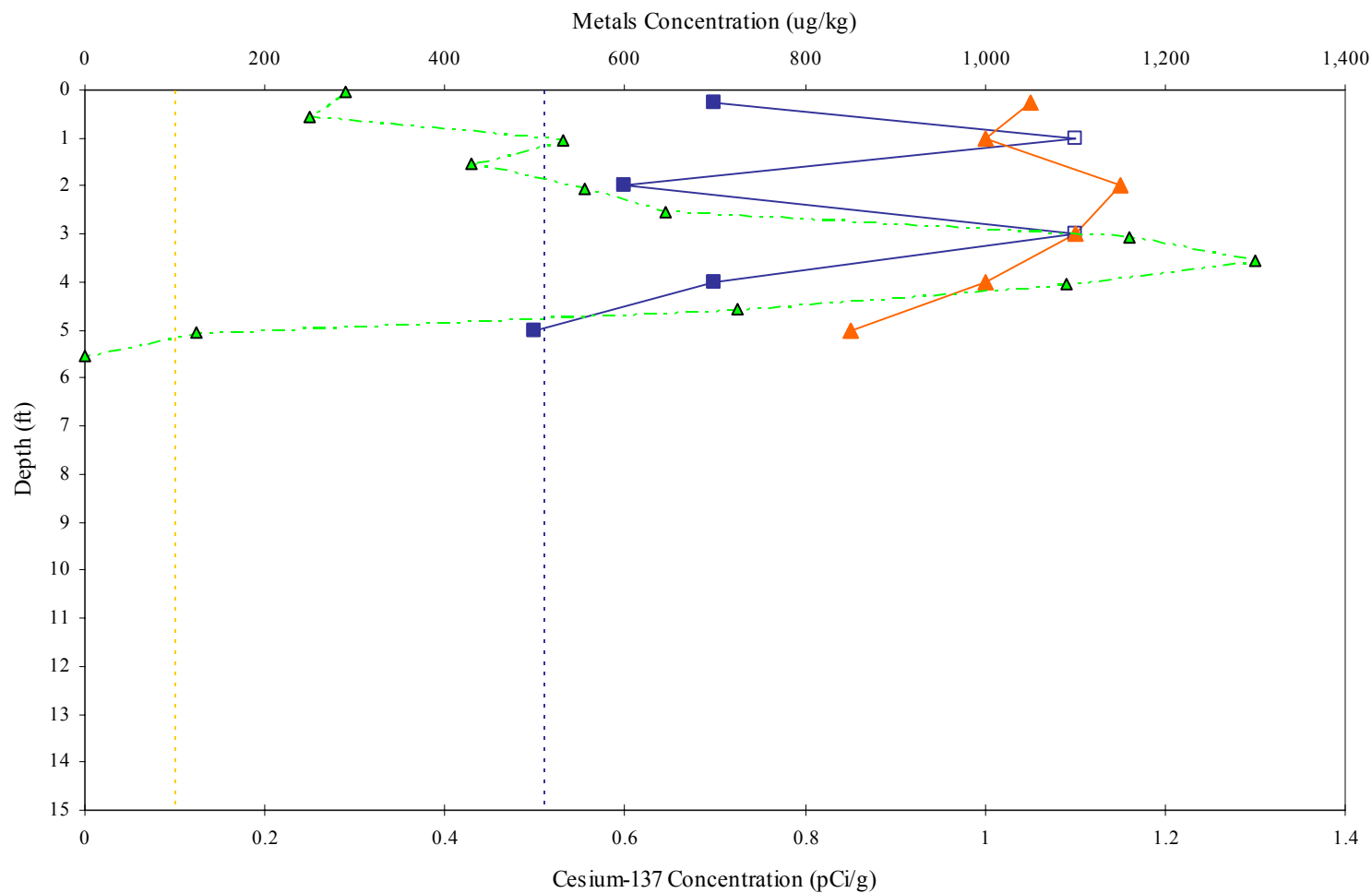
Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Legend

Beryllium Detect
Beryllium Nondetect
Thallium Detect
Thallium Nondetect
Beryllium Background
Thallium Background
Cesium-137

Location

June 1995, River Mile 3.3
TSI Location 286

Notes

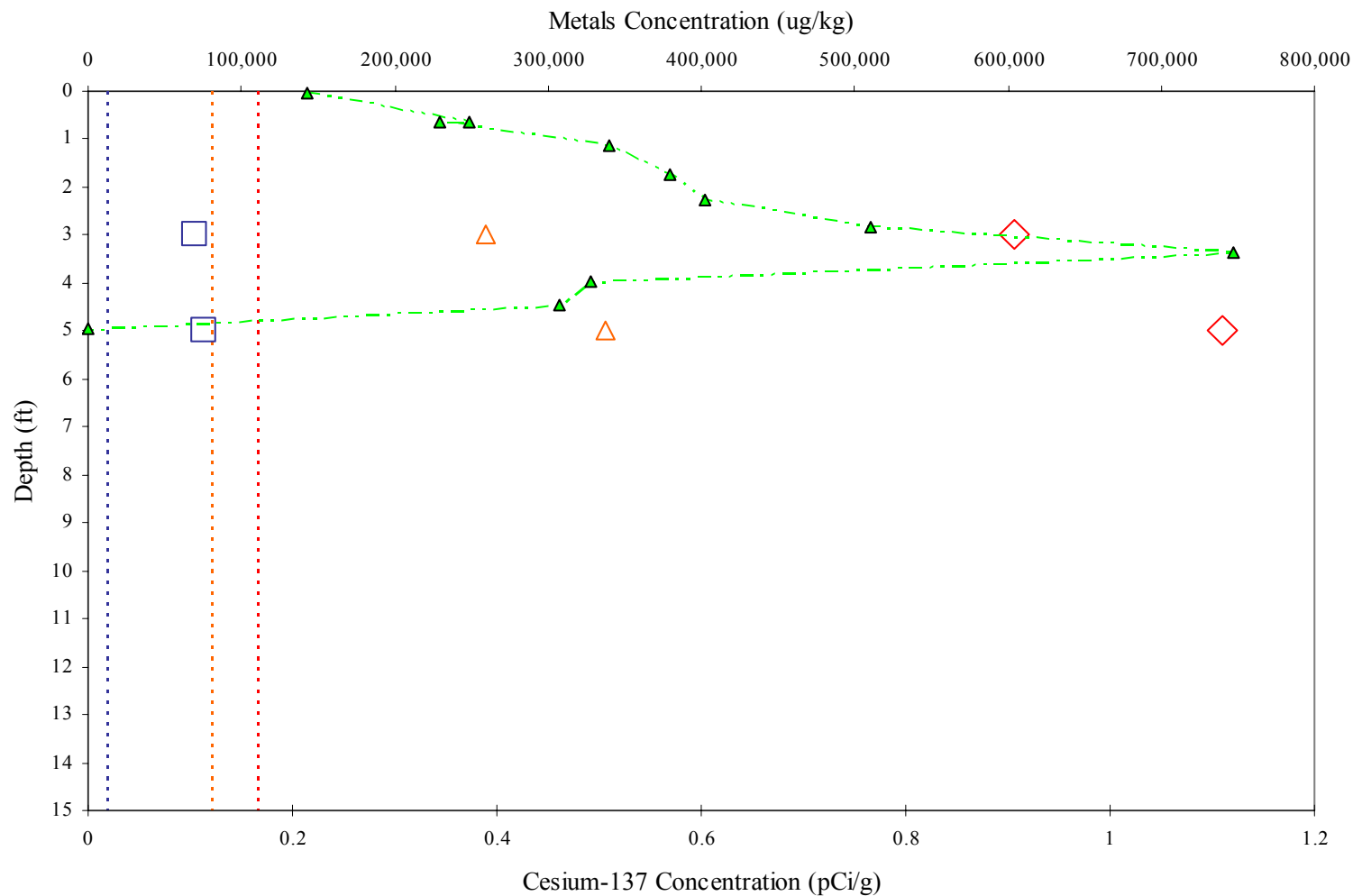Metals background concentrations were taken from Sanders, P.F., May 2003. "Ambient Levels of Metals in New Jersey Soils." Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Beryllium and Thallium
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-9f

February 2006
Draft
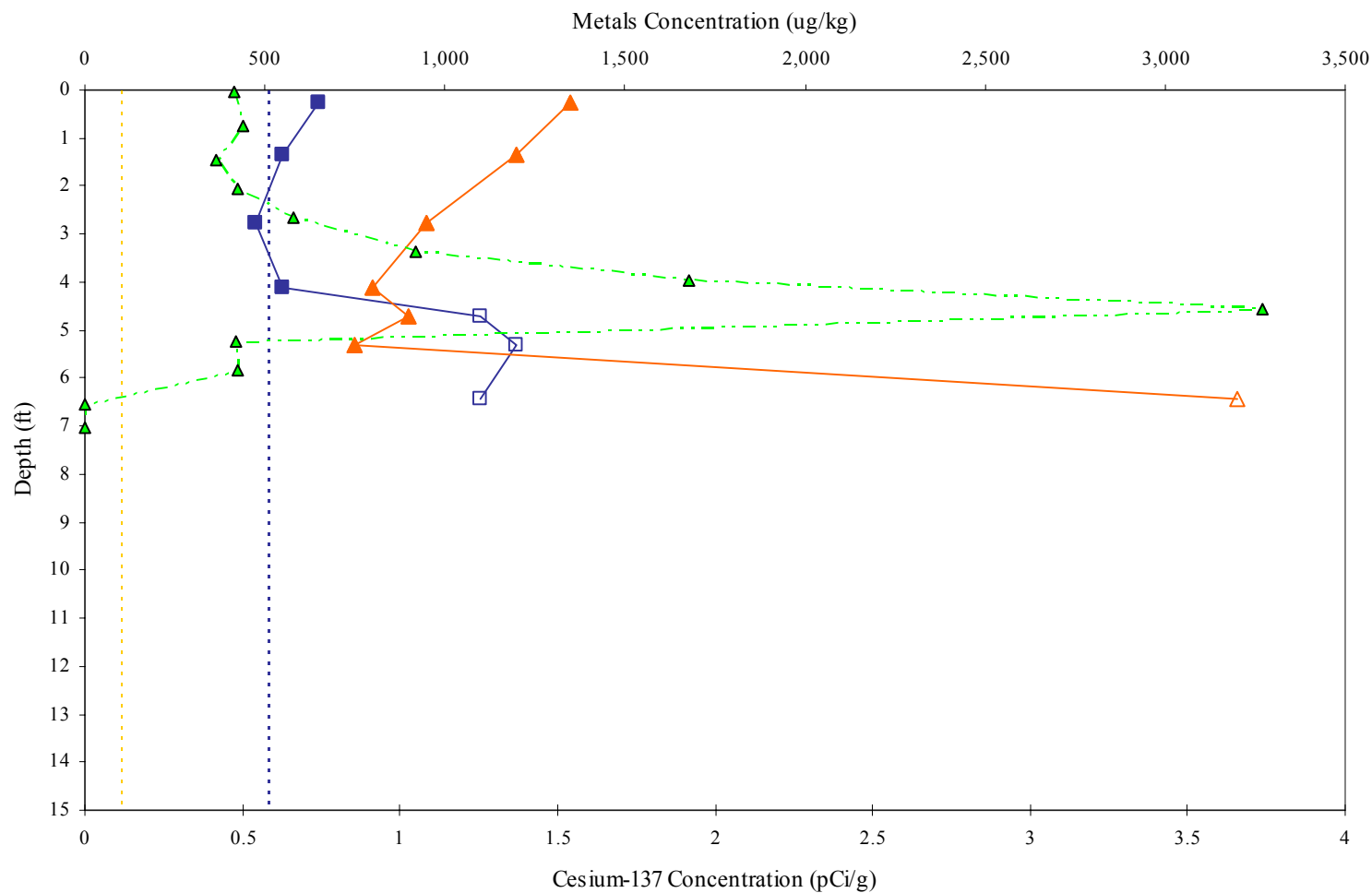
Metals Concentration (ug/kg)

Legend

- Beryllium Detect
- Beryllium Nondetect
- Thallium Detect
- Thallium Nondetect
- Beryllium Background
- Thallium Background
- Cesium-137

Location

May 1995, River Mile 3.6
TSI Location 235

Notes

Metals background concentrations were taken from Sanders, P.F., May 2003. "Ambient Levels of Metals in New Jersey Soils."
Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Cesium-137 Concentration (pCi/g)

Downcore Profile for Beryllium and Thallium
(River Mile 3.6)
Lower Passaic River Restoration Project

Figure 4-9g

February 2006
Draft
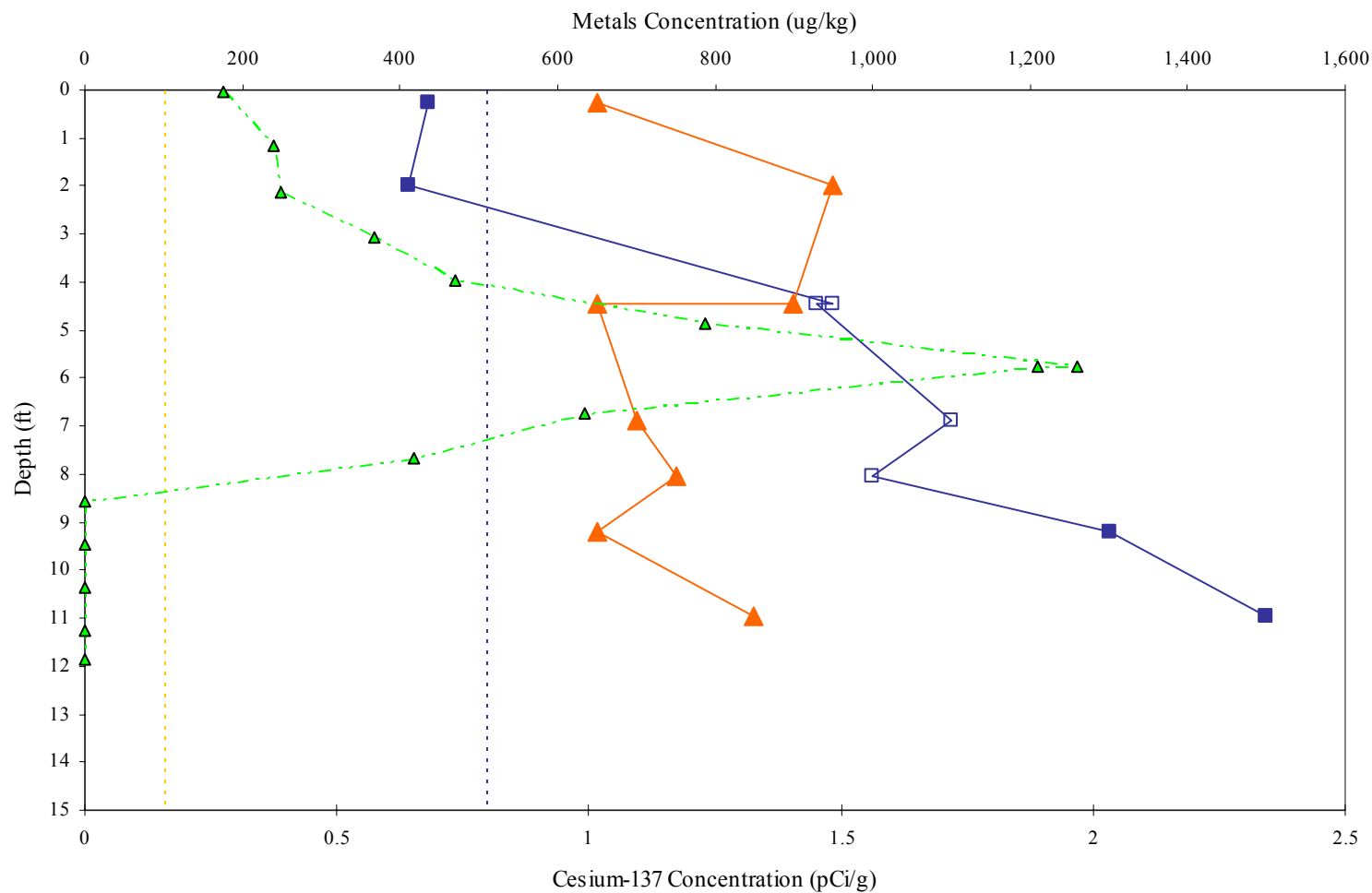
Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Downcore Profile for Beryllium and Thallium
(River Mile 4.0)
Lower Passaic River Restoration Project

Figure 4-9h

February 2006
Draft
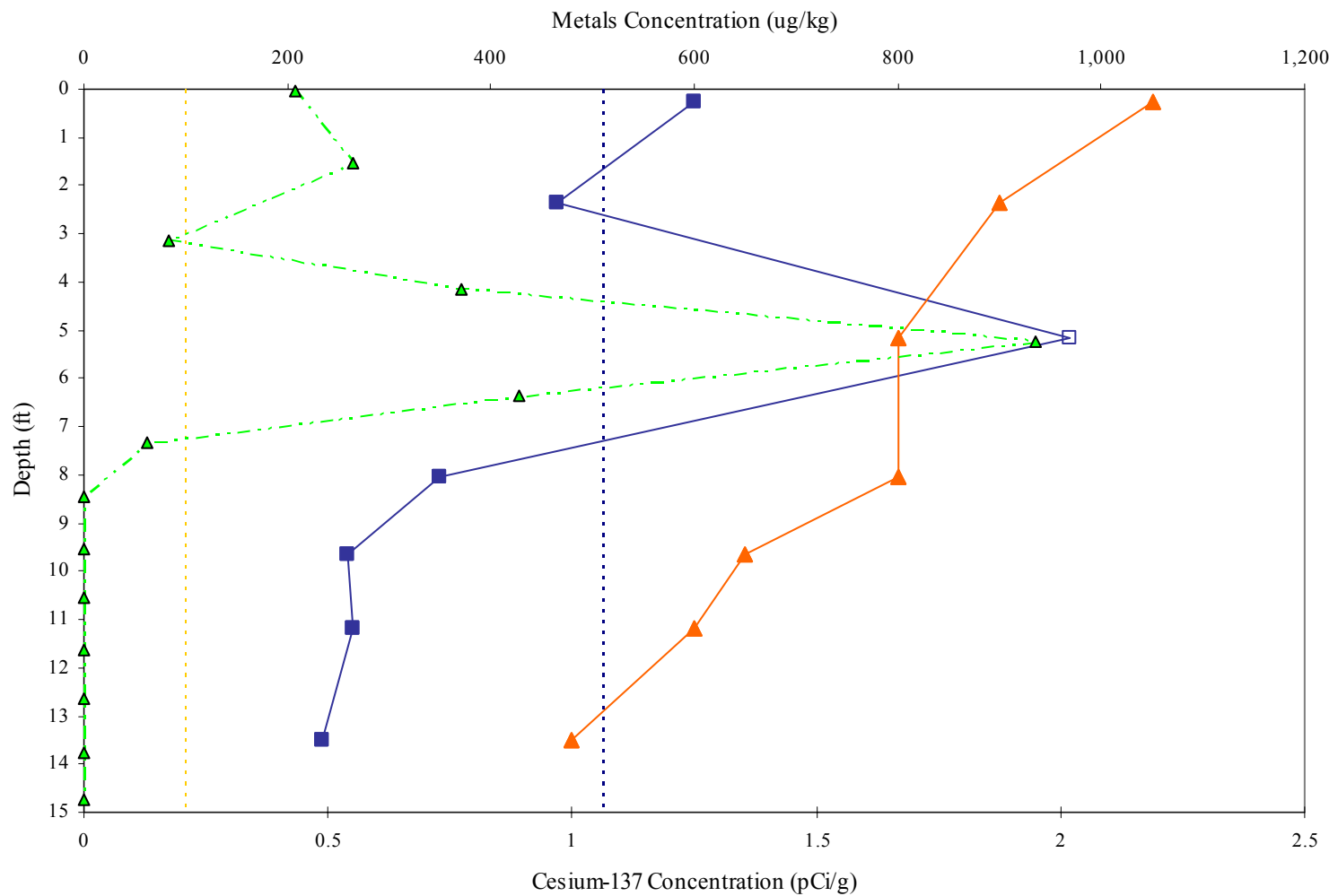
US Army Corps
of Engineers®

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Location

May 1995, River Mile 4.5
TSI Location 248

Notes

Metals background concentrations were taken
from Sanders, P.F., May 2003. "Ambient Levels
of Metals in New Jersey Soils."
Available online: http://www.state.nj.us/dep/
dsr/research/ambient-levels-metal.pdf

US Army Corps
of Engineers®

noaa

Downcore Profile for Beryllium and Thallium
(River Mile 4.5)

Lower Passaic River Restoration Project

Figure 4-9i

February 2006
Draft
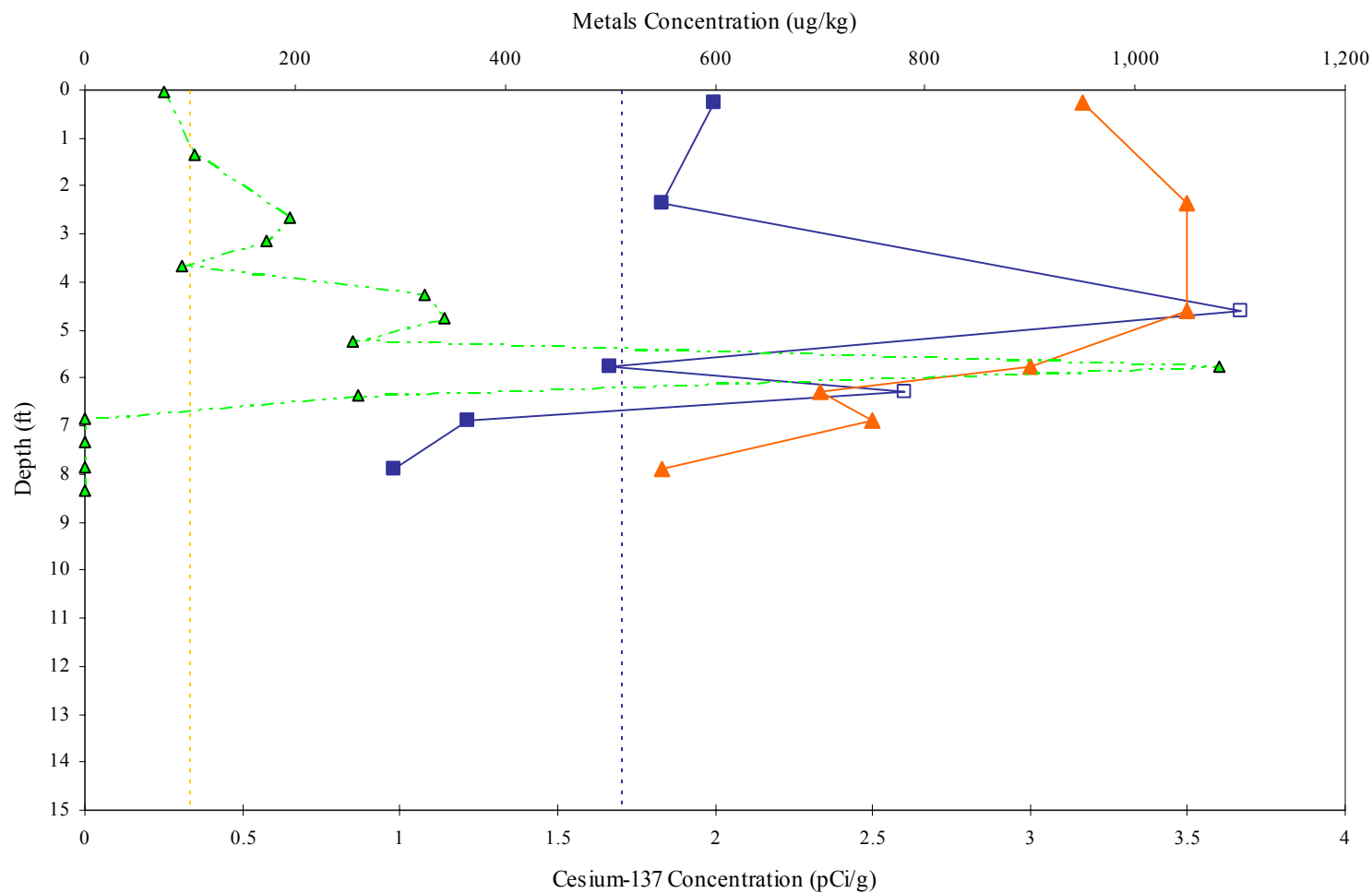
MALCOLM
PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Legend

Beryllium Detect
Beryllium Nondetect
Thallium Detect
Thallium Nondetect
Beryllium Background
Thallium Background
Cesium-137

Location

May 1995, River Mile 4.7
TSI Location 251

Notes

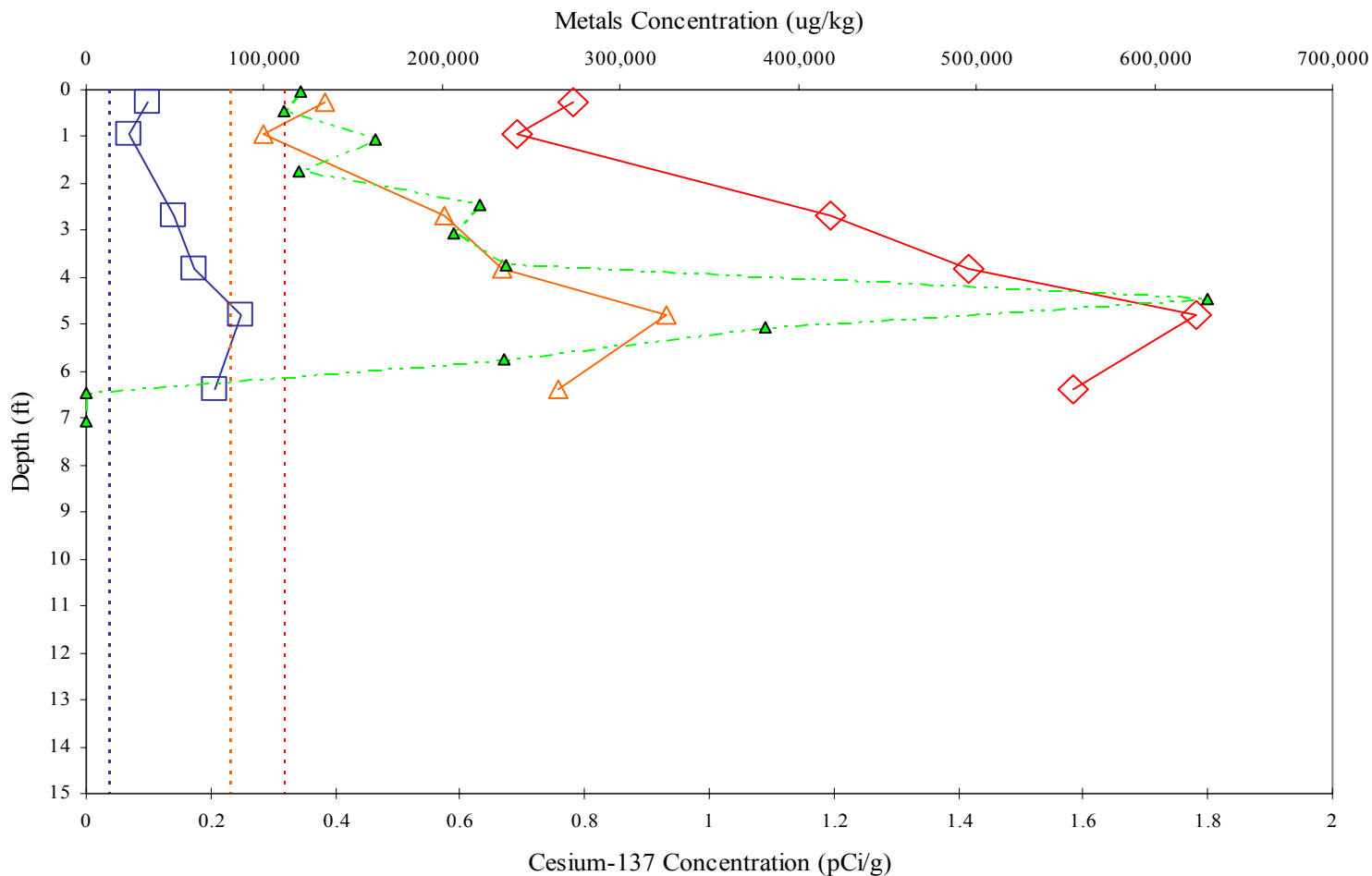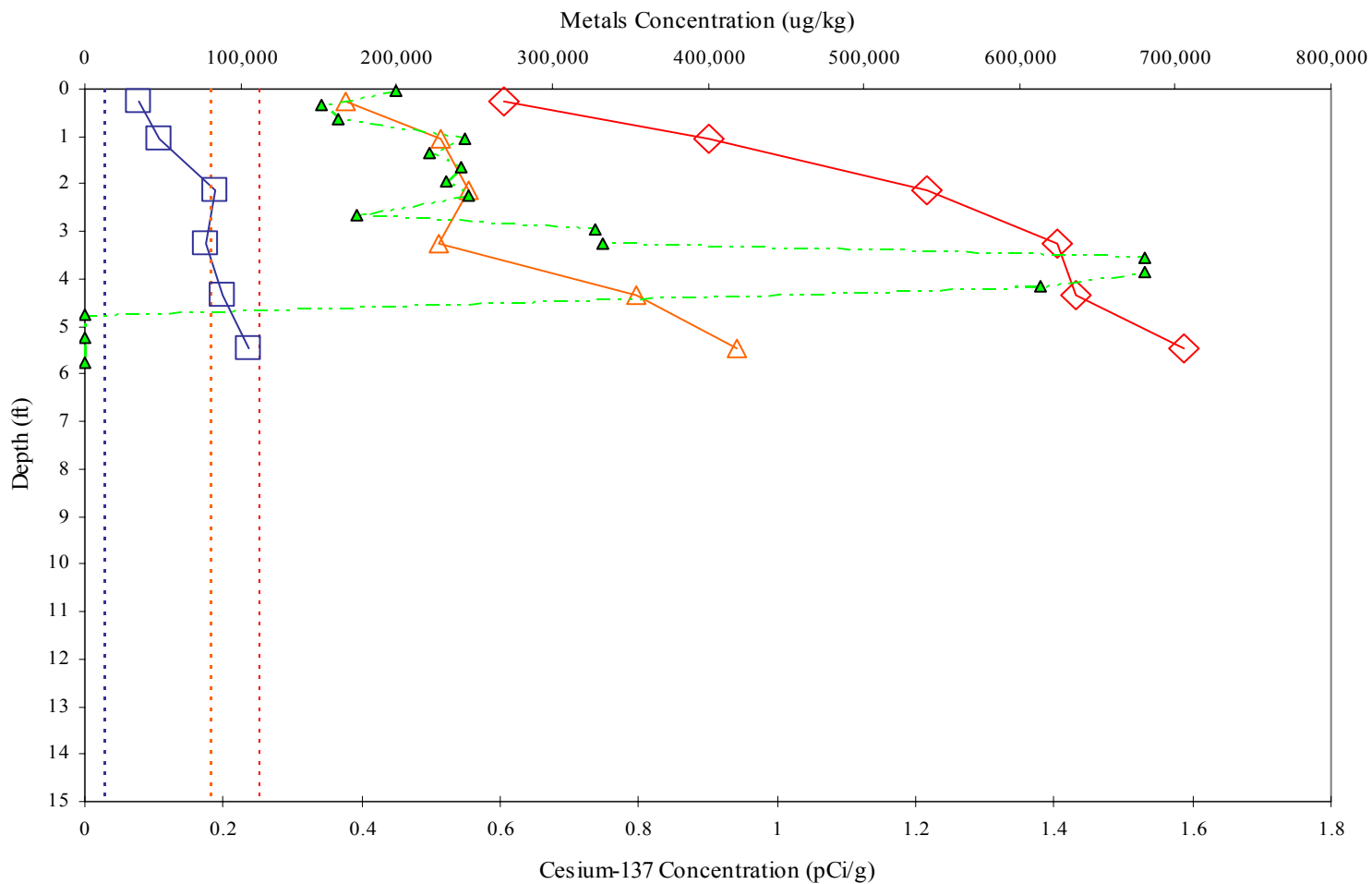Metals background concentrations were taken from Sanders, P.F., May 2003. "Ambient Levels of Metals in New Jersey Soils." Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Beryllium and Thallium
(River Mile 4.7)
Lower Passaic River Restoration Project

Figure 4-9j

February 2006
Draft
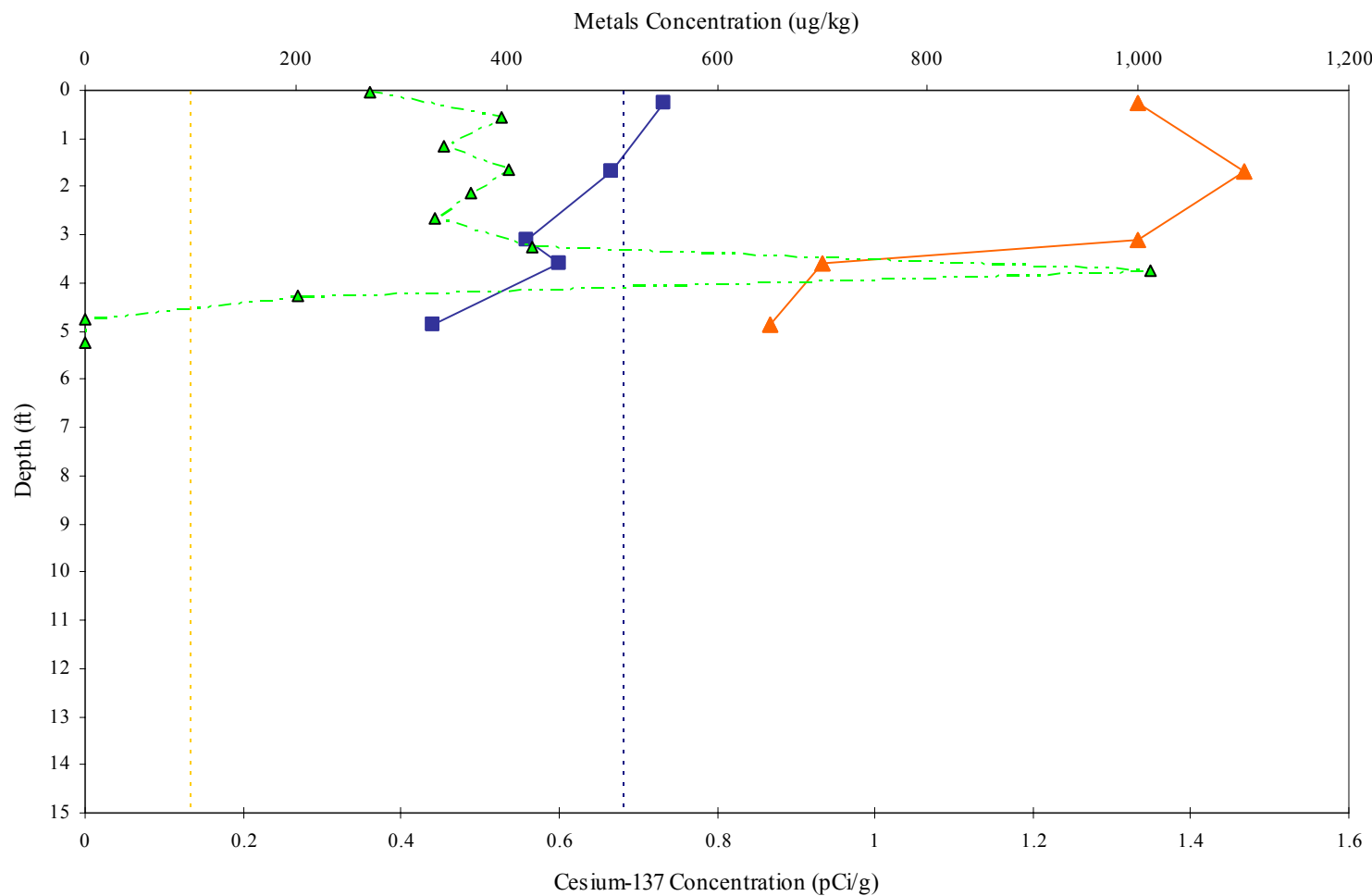
Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Beryllium and Thallium
(River Mile 4.9)
Lower Passaic River Restoration Project

Figure 4-9k

February 2006
Draft

Legend

- Beryllium Detect
- Beryllium Nondetect
- Thallium Detect
- Thallium Nondetect
- Beryllium Background
- Thallium Background
- Cesium-137

Location

May 1995, River Mile 6.3
TSI Location 272

Notes

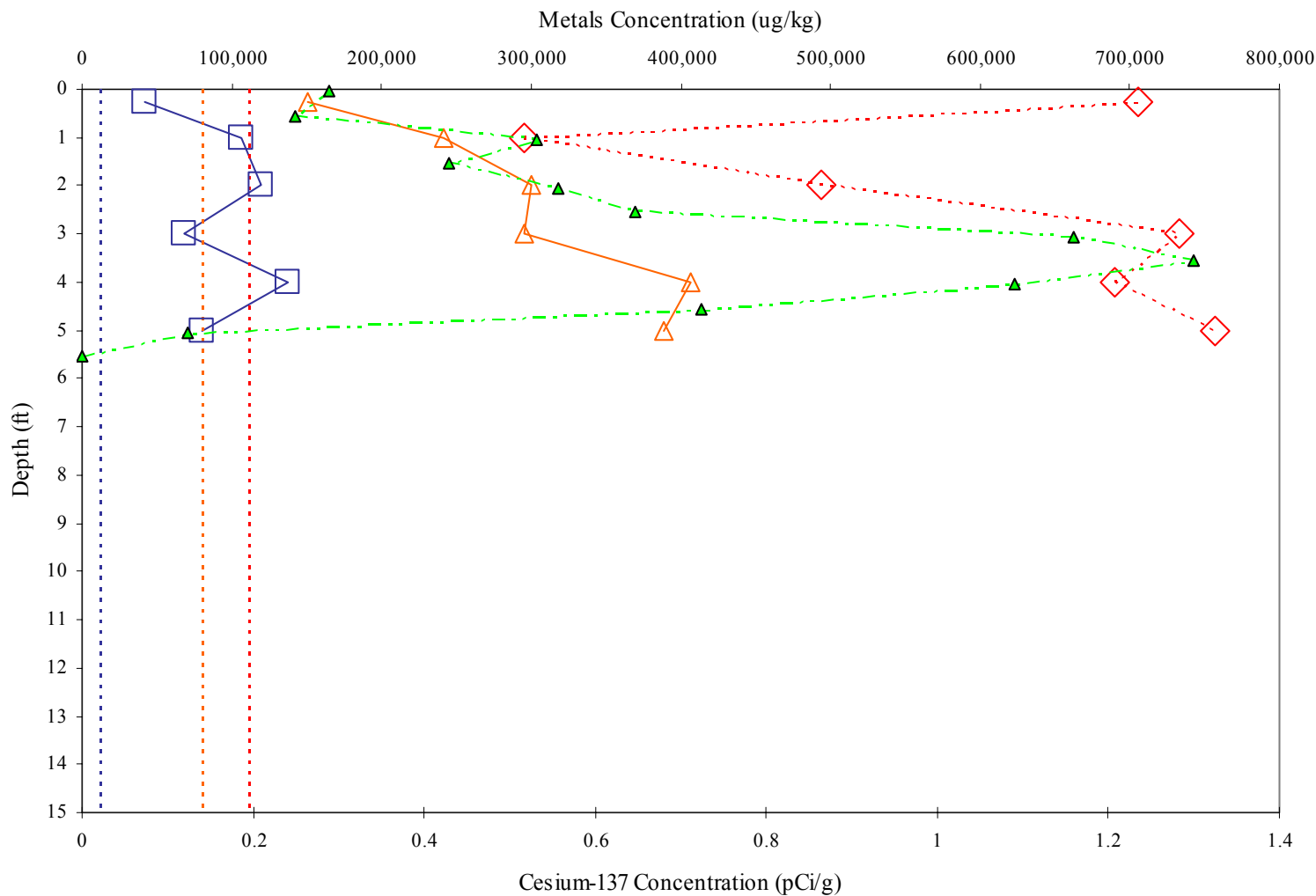Metals background concentrations were taken from Sanders, P.F., May 2003. "Ambient Levels of Metals in New Jersey Soils." Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Metals Concentration (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Downcore Profile for Beryllium and Thallium
(River Mile 6.3)
Lower Passaic River Restoration Project

Figure 4-9l

February 2006
Draft

Legend

- Beryllium Detect
- Beryllium Nondetect
- Thallium Detect
- Thallium Nondetect
- Beryllium Background
- Thallium Background
- Cesium-137

Location

June 1995, River Mile 6.4
TSI Location 298

Notes

Metals background concentrations were taken
from Sanders, P.F., May 2003. "Ambient Levels
of Metals in New Jersey Soils."
Available online: http://www.state.nj.us/dep/
dsr/research/ambient-levels-metal.pdf

Downcore Profile for Beryllium and Thallium
(River Mile 6.4)
Lower Passaic River Restoration Project

Figure 4-9m

February 2006
Draft
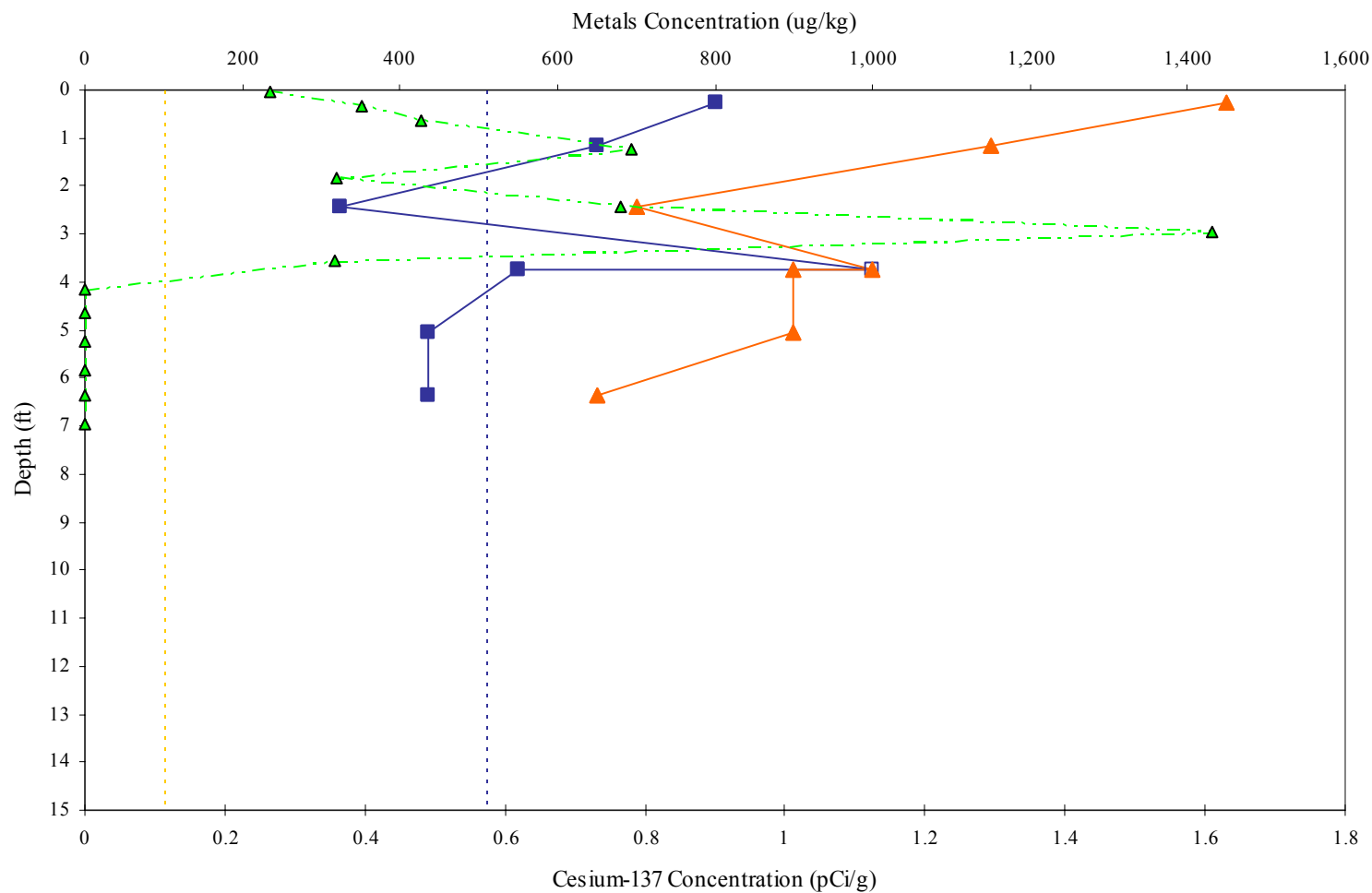
Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Location

June 1995, River Mile 6.5
TSI Location 275

Notes

Metals background concentrations were taken
from Sanders, P.F., May 2003. "Ambient Levels
of Metals in New Jersey Soils."
Available online: http://www.state.nj.us/dep/
dsr/research/ambient-levels-metal.pdf

Downcore Profile for Beryllium and Thallium
(River Mile 6.5)
Lower Passaic River Restoration Project

Figure 4-9n

February 2006
Draft
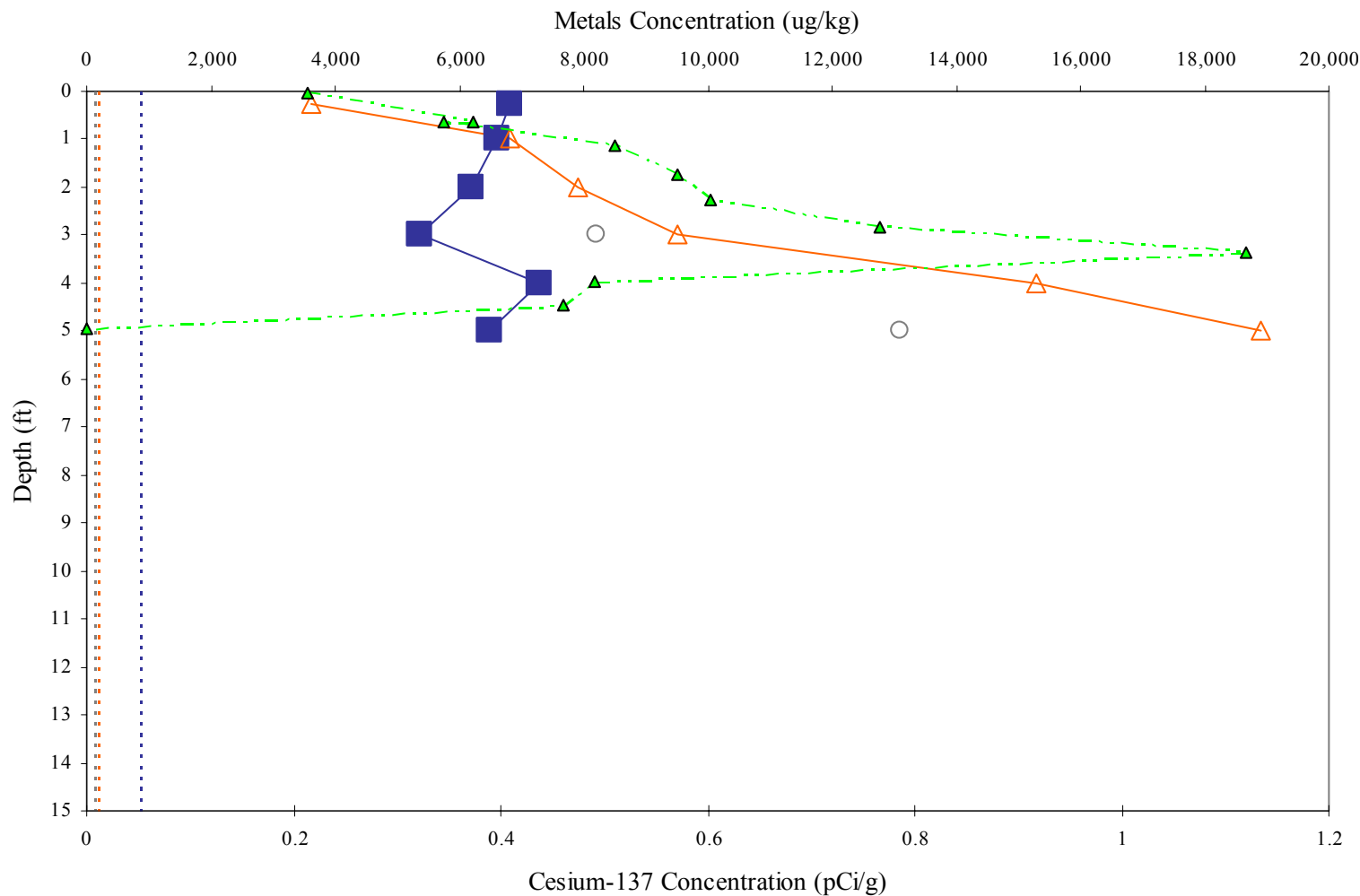
MALCOLM
PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Location

April 1995, River Mile 1.5
TSI Location 209

Notes

Metals background concentrations were taken from Saunders, P. F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Discontinuity in detected silver is due to an absence of data at an average depth of 4 feet.

Downcore Profile for Antimony, Mercury, and Silver (River Mile 1.5)

Lower Passaic River Restoration Project

US Army Corps of Engineers®

Figure 4-10a

February 2006
Draft
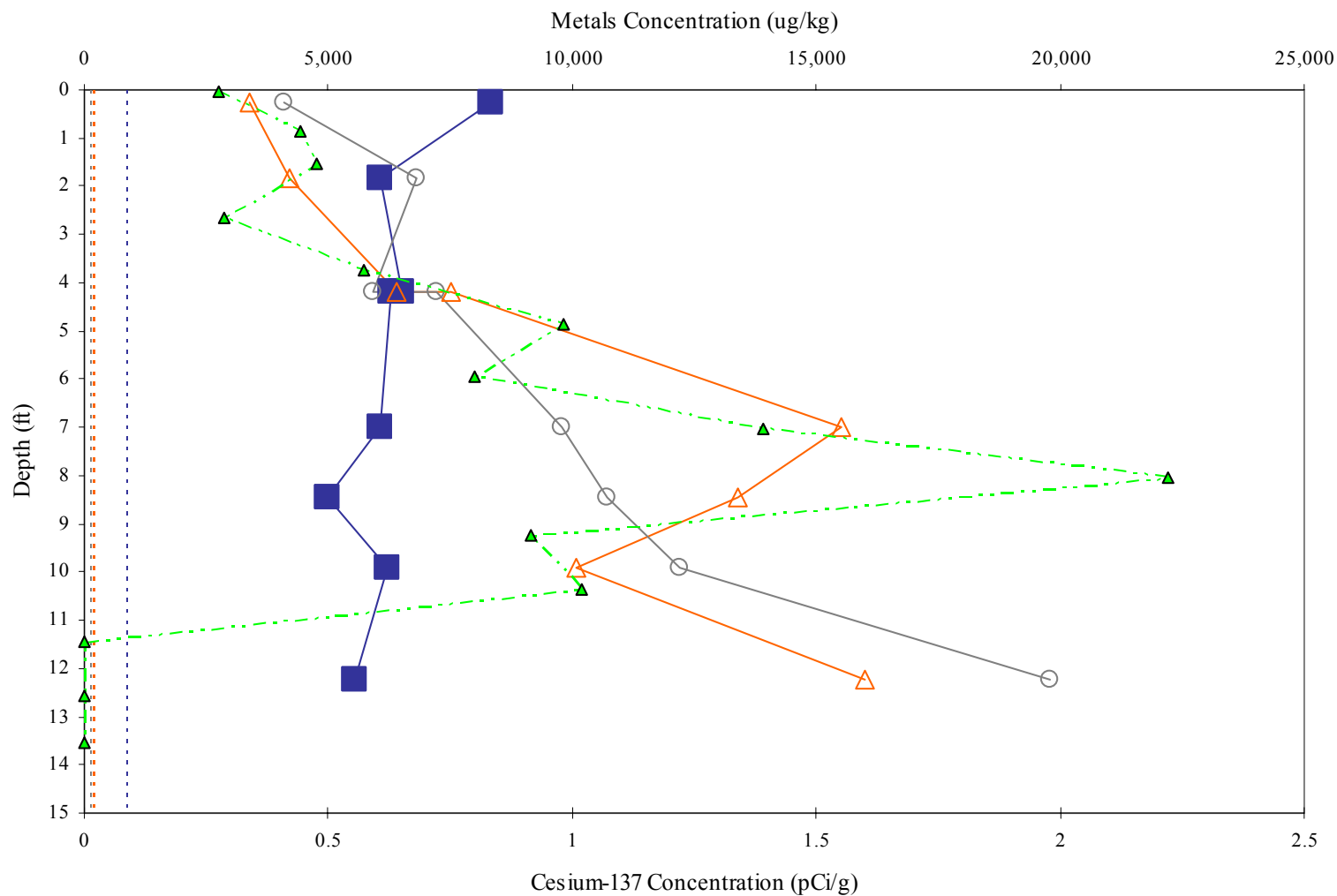
MALCOLM PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Antimony, Mercury, and Silver (River Mile 2.7)

Lower Passaic River Restoration Project

Figure 4-10b

February 2006
Draft
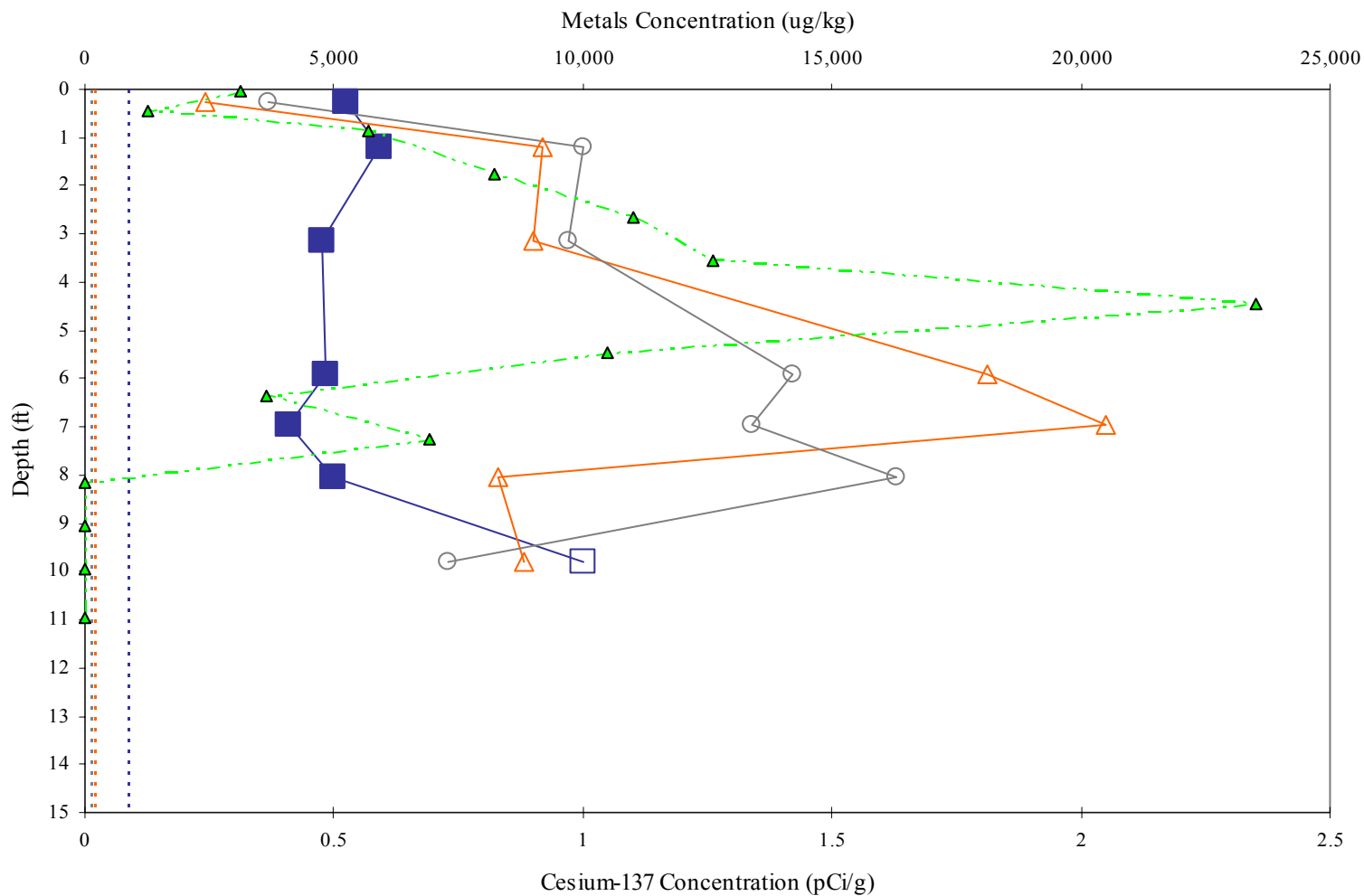
US Army Corps of Engineers®

MALCOLM PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Legend

— □ — Antimony Detect
■ Antimony Nondetect
— △ — Mercury Detect
— ○ — Silver Detect
········ Antimony Background
········ Mercury Background
········ Silver Background
— ▲ — Cesium-137

Location

May 1995, River Mile 3.1
TSI Location 228

Notes

Metals background concentrations were taken from Saunders, P. F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Antimony, Mercury, and Silver (River Mile 3.1)

Lower Passaic River Restoration Project

Figure 4-10c

February 2006
Draft
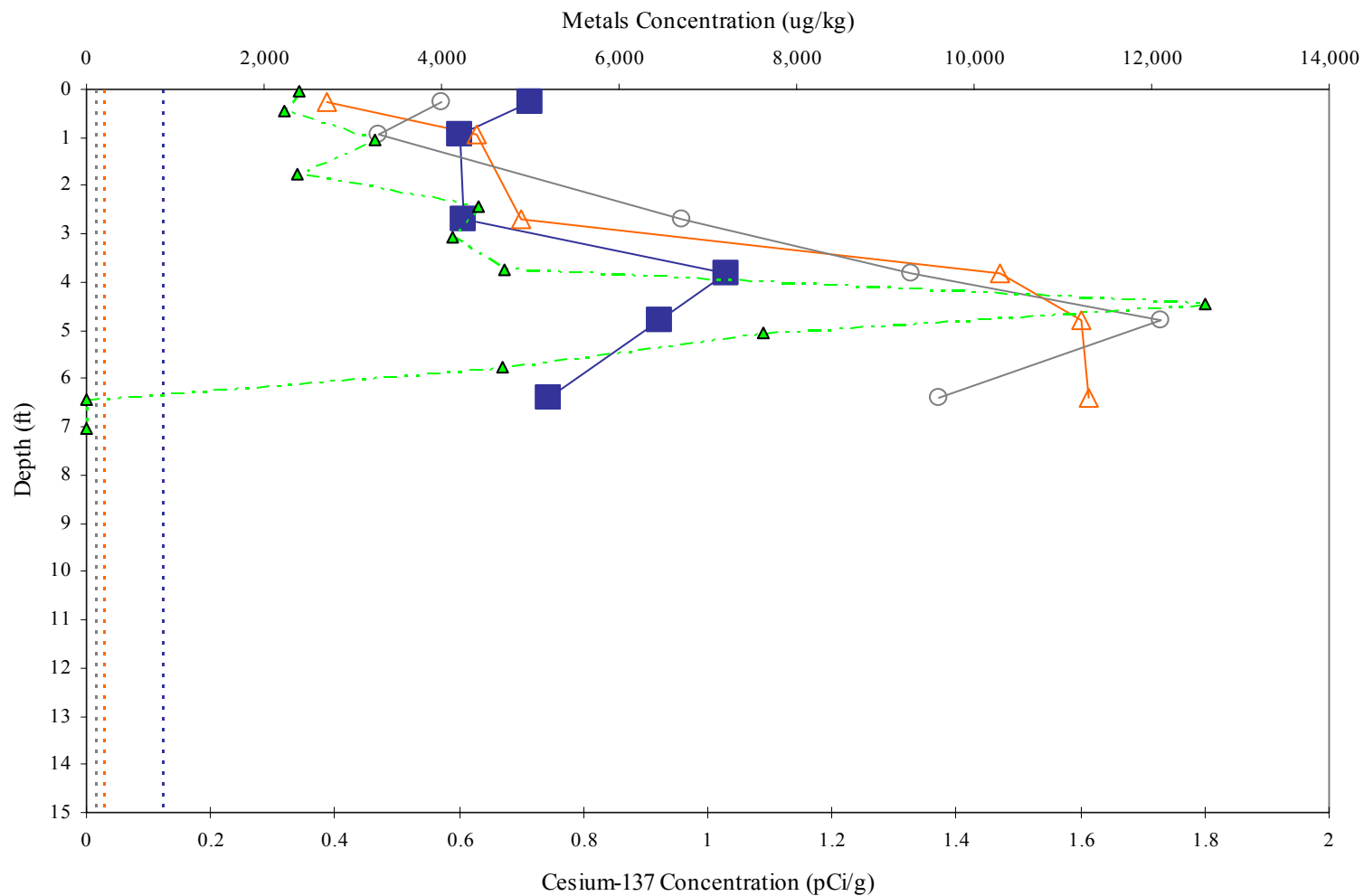
US Army Corps of Engineers®

MALCOLM PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Legend

- Antimony Detect
- Antimony Nondetect
- Mercury Detect
- Silver Detect
- Antimony Background
- Mercury Background
- Silver Background
- Cesium-137

Location

May 1995, River Mile 3.1
TSI Location 230

Notes

Metals background concentrations were taken from Saunders, P. F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Antimony, Mercury, and Silver (River Mile 3.1)

Lower Passaic River Restoration Project

Figure 4-10d

February 2006
Draft
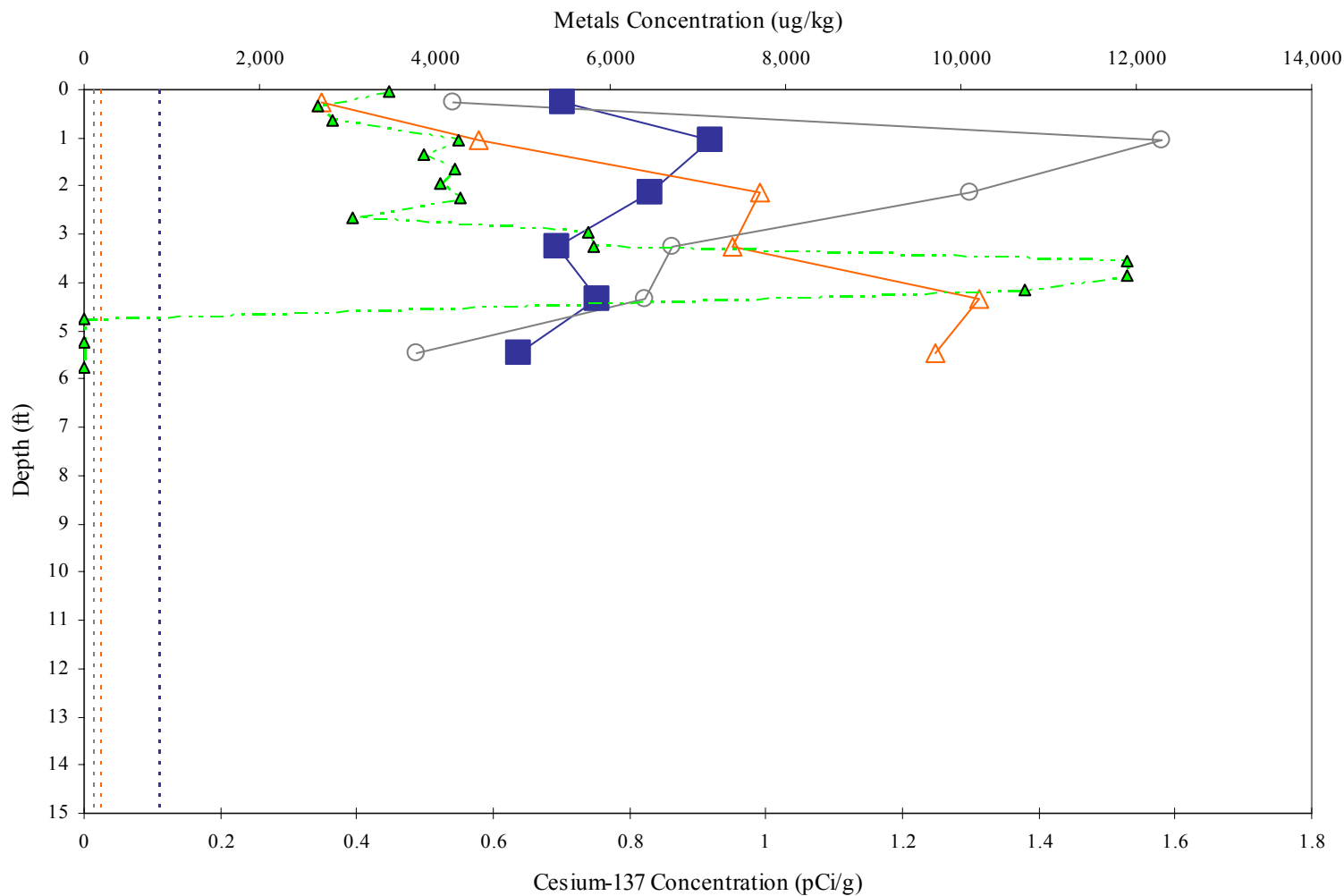
US Army Corps of Engineers

MALCOLM PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Legend

- □ Antimony Detect
- ■ Antimony Nondetect
- △ Mercury Detect
- ○ Silver Detect
- ⋯⋯ Antimony Background
- ⋯⋯ Mercury Background
- ⋯⋯ Silver Background
- ▲ Cesium-137

Location

May 1995, River Mile 3.3
TSI Location 232

Notes

Metals background concentrations were taken from Saunders, P. F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Antimony, Mercury, and Silver (River Mile 3.3)

Lower Passaic River Restoration Project

Figure 4-10e

February 2006
Draft
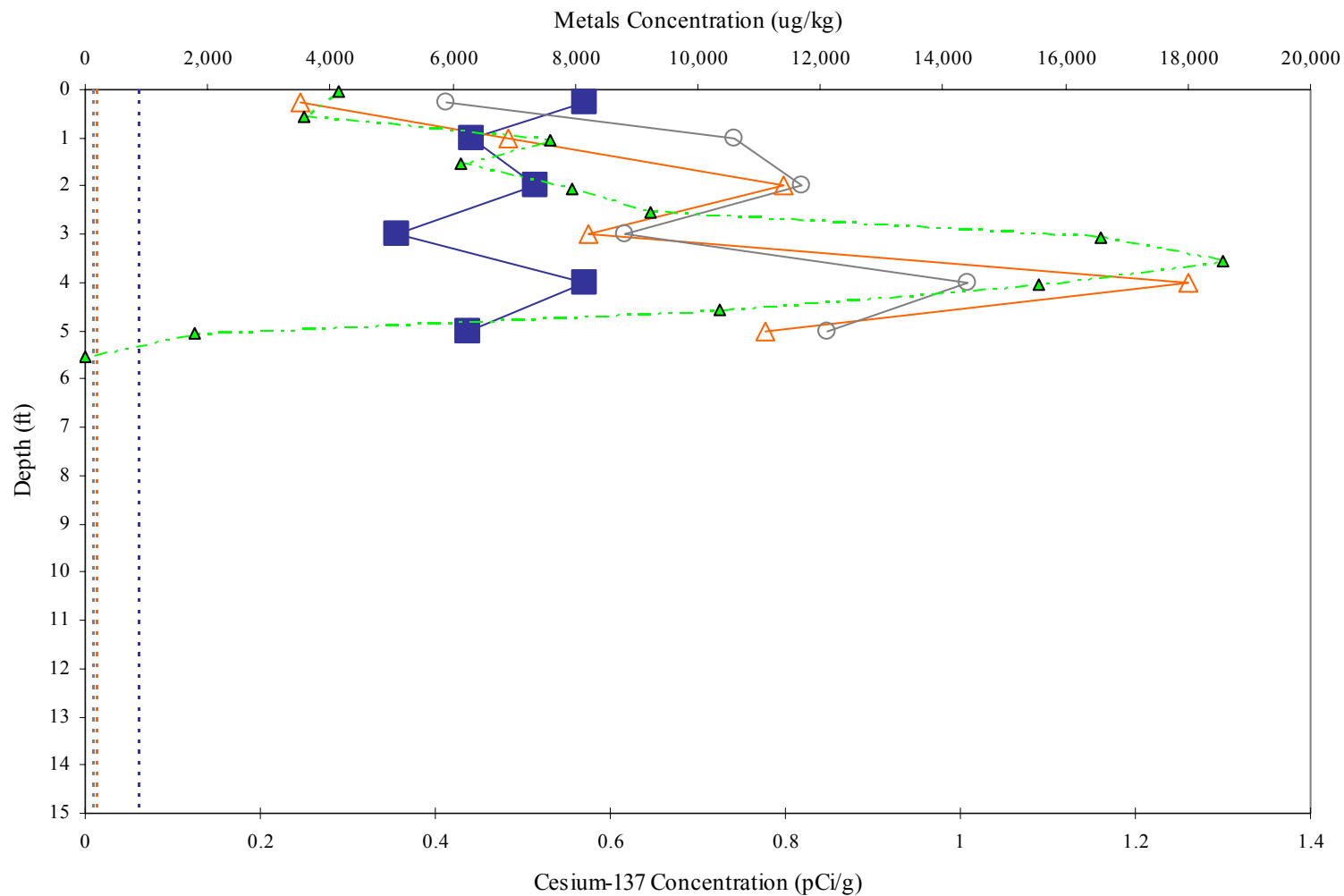
US Army Corps of Engineers®

MALCOLM PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Antimony, Mercury, and Silver
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-10f

February 2006
Draft

MALCOLM PIRNIE

US Army Corps of Engineers

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Location

May 1995, River Mile 3.6
TSI Location 235

Notes

Metals background concentrations were taken from Saunders, P. F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Antimony, Mercury, and Silver (River Mile 3.6)

Lower Passaic River Restoration Project

Figure 4-10g

February 2006
Draft

Metals Concentration (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Legend

Antimony Detect
Antimony Nondetect
Mercury Detect
Silver Detect
Antimony Background
Mercury Background
Silver Background
Cesium-137

Location

May 1995, River Mile 4.0
TSI Location 241

Notes

Metals background concentrations were taken from Saunders, P. F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Antimony, Mercury, and Silver (River Mile 4.0)

Lower Passaic River Restoration Project

Figure 4-10h

February 2006
Draft

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)
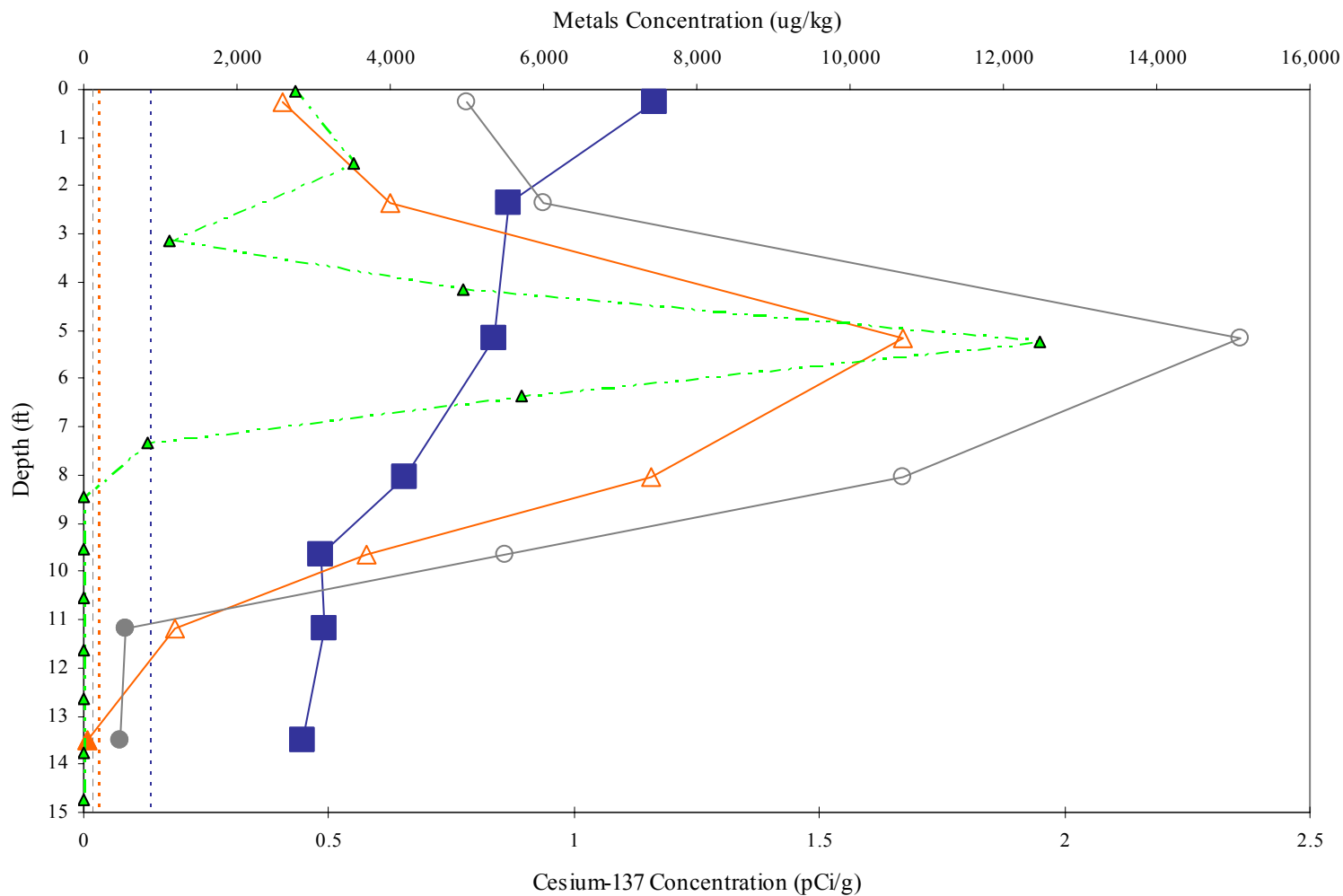
Legend

- Antimony Detect
- Antimony Nondetect
- Mercury Detect
- Mercury Nondetect
- Silver Detect
- Silver Nondetect
- Antimony Background
- Mercury Background
- Silver Background
- Cesium-137

Location

May 1995, River Mile 4.5
TSI Location 248

Notes

Metals background concentrations were taken from Saunders, P. F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online:
http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Antimony, Mercury, and Silver (River Mile 4.5)

Lower Passaic River Restoration Project

Figure 4-10i

February 2006
Draft

Downcore Profile for Antimony, Mercury, and Silver
(River Mile 4.7)

Lower Passaic River Restoration Project

Figure 4-10j

February 2006
Draft
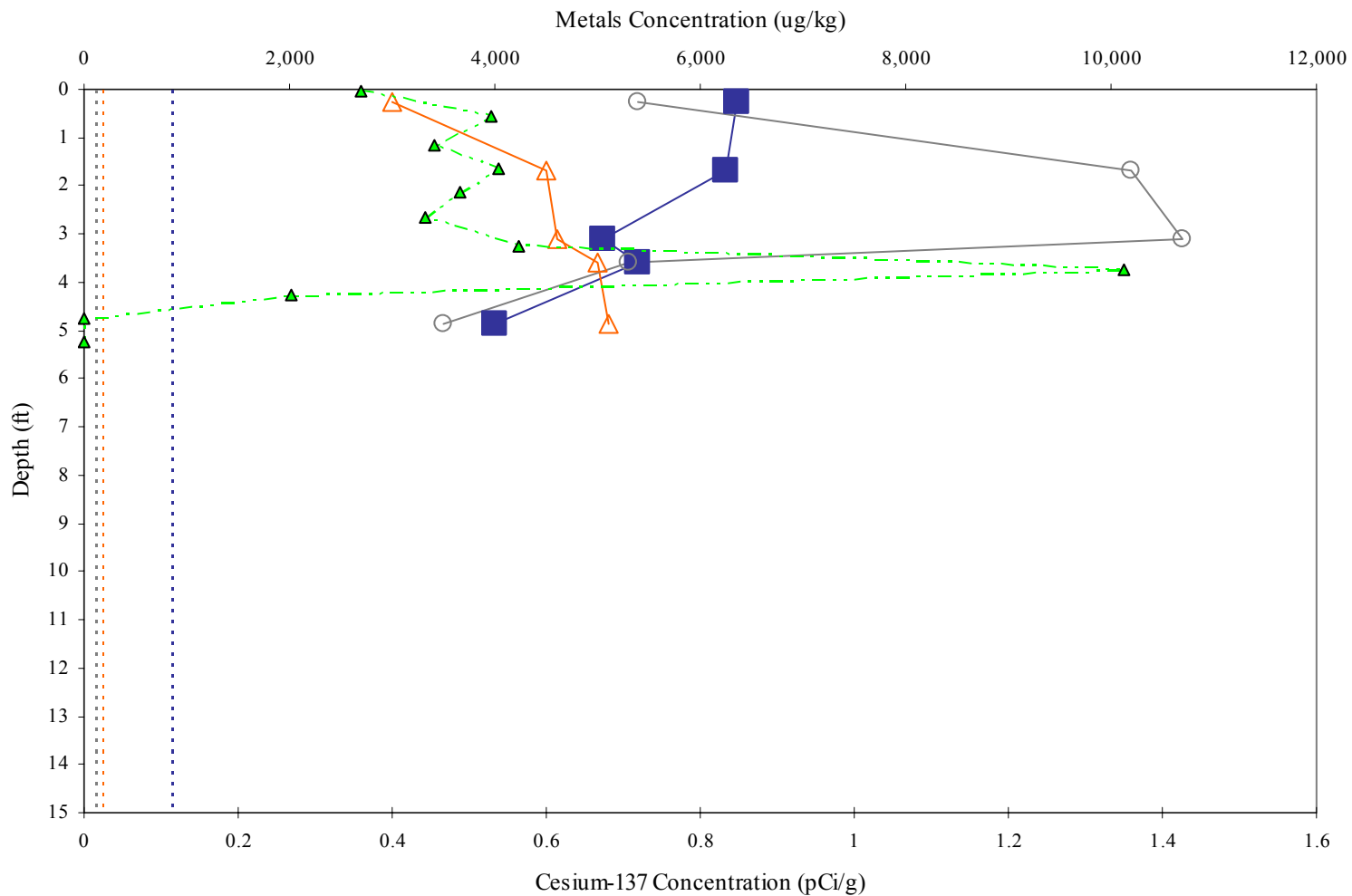
Metals Concentration (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Legend

- Antimony Detect
- Antimony Nondetect
- Mercury Detect
- Silver Detect
- Antimony Background
- Mercury Background
- Silver Background
- Cesium-137

Location

May 1995, River Mile 4.9
TSI Location 253

Notes

Metals background concentrations were taken from Saunders, P. F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Antimony, Mercury, and Silver (River Mile 4.9)

Lower Passaic River Restoration Project

Figure 4-10k

February 2006
Draft

US Army Corps of Engineers®

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Legend

— □ — Antimony Detect
— ■ — Antimony Nondetect
— △ — Mercury Detect
— ○ — Silver Detect
········ Antimony Background
········ Mercury Background
········ Silver Background
—·▲·— Cesium-137

Location

May 1995, River Mile 6.3
TSI Location 272

Notes

Metals background concentrations were taken from Saunders, P. F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Antimony, Mercury, and Silver
(River Mile 6.3)
Lower Passaic River Restoration Project

Figure 4-10I

February 2006
Draft

US Army Corps of Engineers®

MALCOLM PIRNIE

Metals Concentration (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Legend

- Antimony Detect
- Antimony Nondetect
- Mercury Detect
- Silver Detect
- Antimony Background
- Mercury Background
- Silver Background
- Cesium-137

Location

June 1995, River Mile 6.4
TSI Location 298

Notes

Metals background concentrations were taken from Saunders, P. F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Antimony, Mercury, and Silver (River Mile 6.4)
Lower Passaic River Restoration Project

Figure 4-10m

February 2006
Draft

Downcore Profile for Antimony, Mercury, and Silver (River Mile 6.5)

Lower Passaic River Restoration Project

Figure 4-10n

February 2006
Draft

Legend

- Antimony Detect
- Antimony Nondetect
- Mercury Detect
- Silver Detect
- Antimony Background
- Mercury Background
- Silver Background
- Cesium-137

Location

June 1995, River Mile 6.5
TSI Location 275

Notes

Metals background concentrations were taken from Saunders, P. F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Figure 4-11a

Downcore Profile for Nickel, Barium, and Lead
(River Mile 1.5)

Lower Passaic River Restoration Project
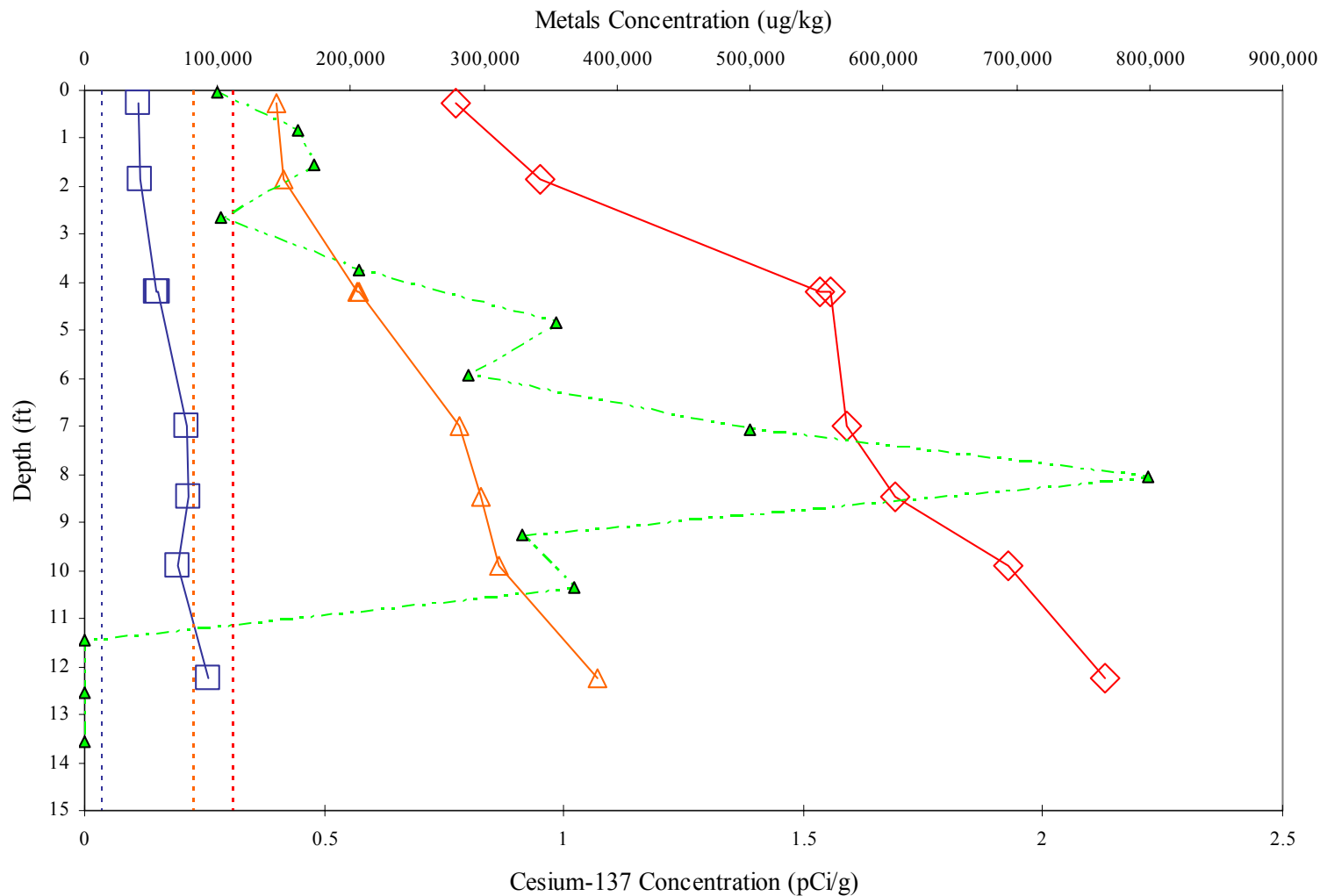
February 2006
Draft

Legend

- Nickel Detect
- Barium Detect
- Lead Detect
- Nickel Background
- Barium Background
- Lead Background
- Cesium-137

Location

April 1995, River Mile 1.5
TSI Location 209

Note:
Metals background concentrations
were taken from Sanders, P.F., May 2003.
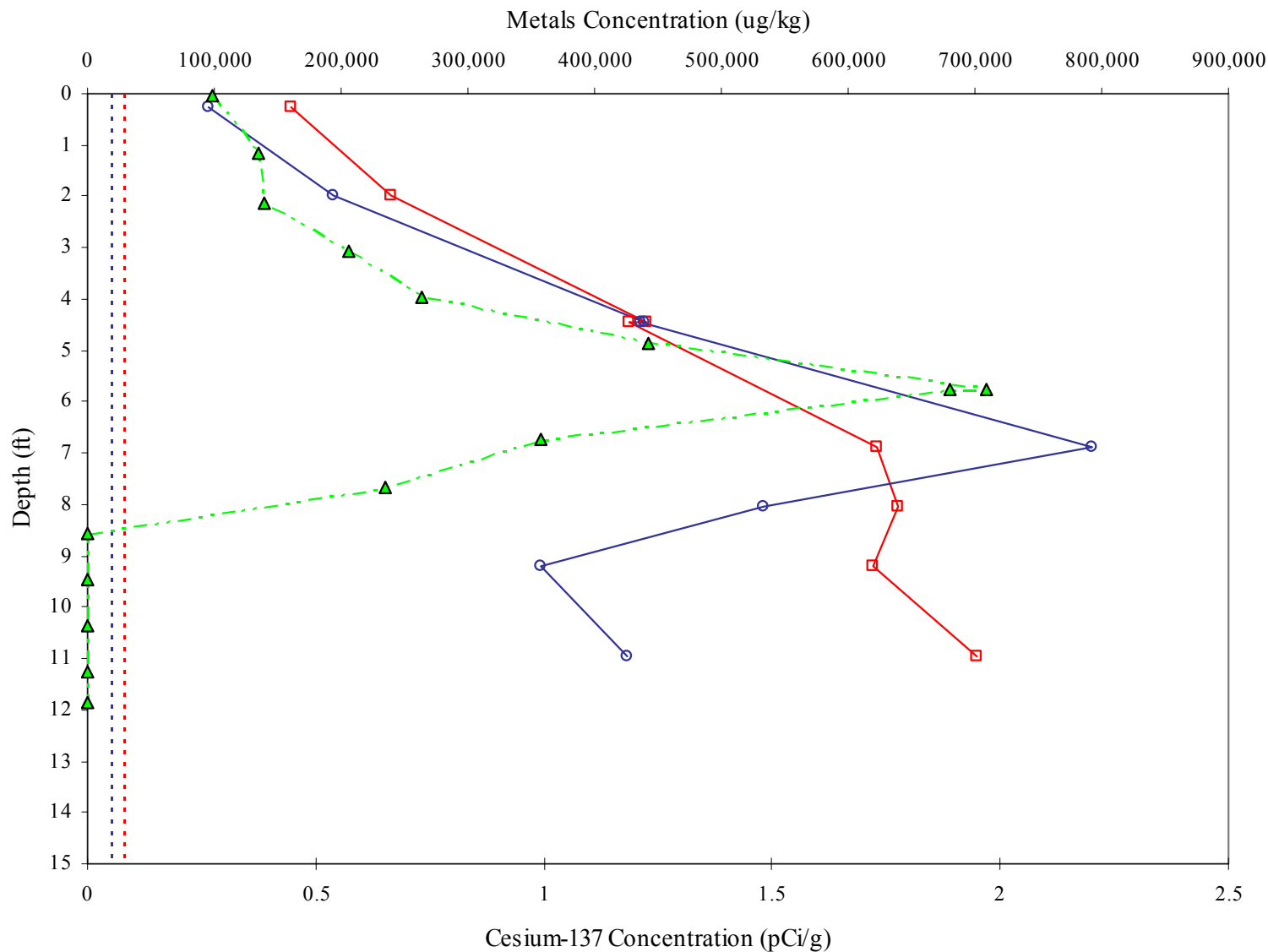"Ambient Levels of Metals in New Jersey
Soils."

Available online: http://www.state.nj.us/
dep/dsr/research/ambient-levels-metal.pdf

Legend

Nickel Detect
Barium Detect
Lead Detect
Nickel Background
Barium Background
Lead Background
Cesium-137

Location

April 1995, River Mile 2.7
TSI Location 222

Note:
Metals background concentrations
were taken from Sanders, P.F.,May 2003.
"Ambient Levels of Metals in New Jersey
Soils."

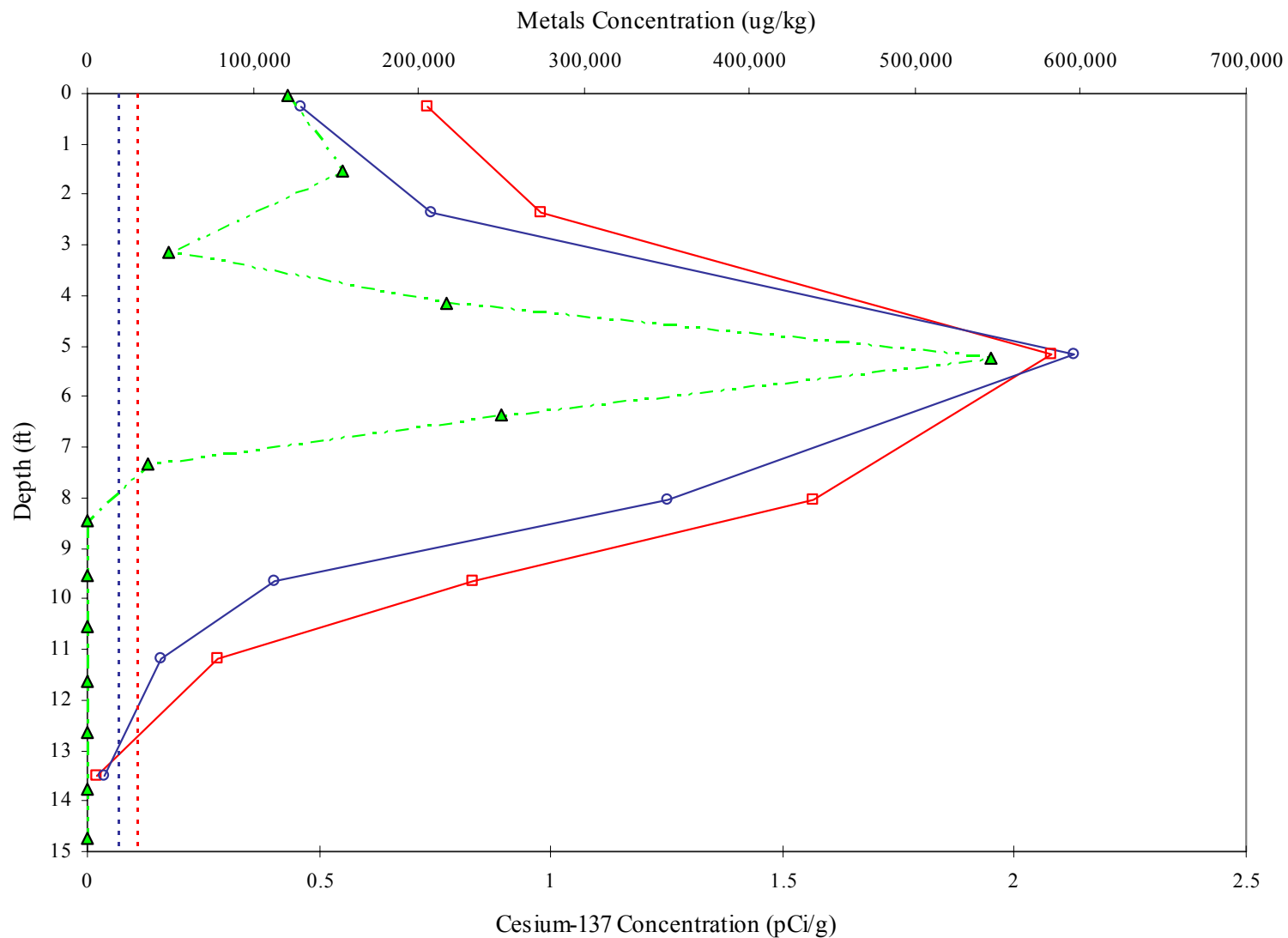Available online: http://www.state.nj.us/
dep/dsr/research/ambient-levels-metal.pdf

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Nickel, Barium, and Lead
(River Mile 2.7)
Lower Passaic River Restoration Project

Figure 4-11b

February 2006
Draft
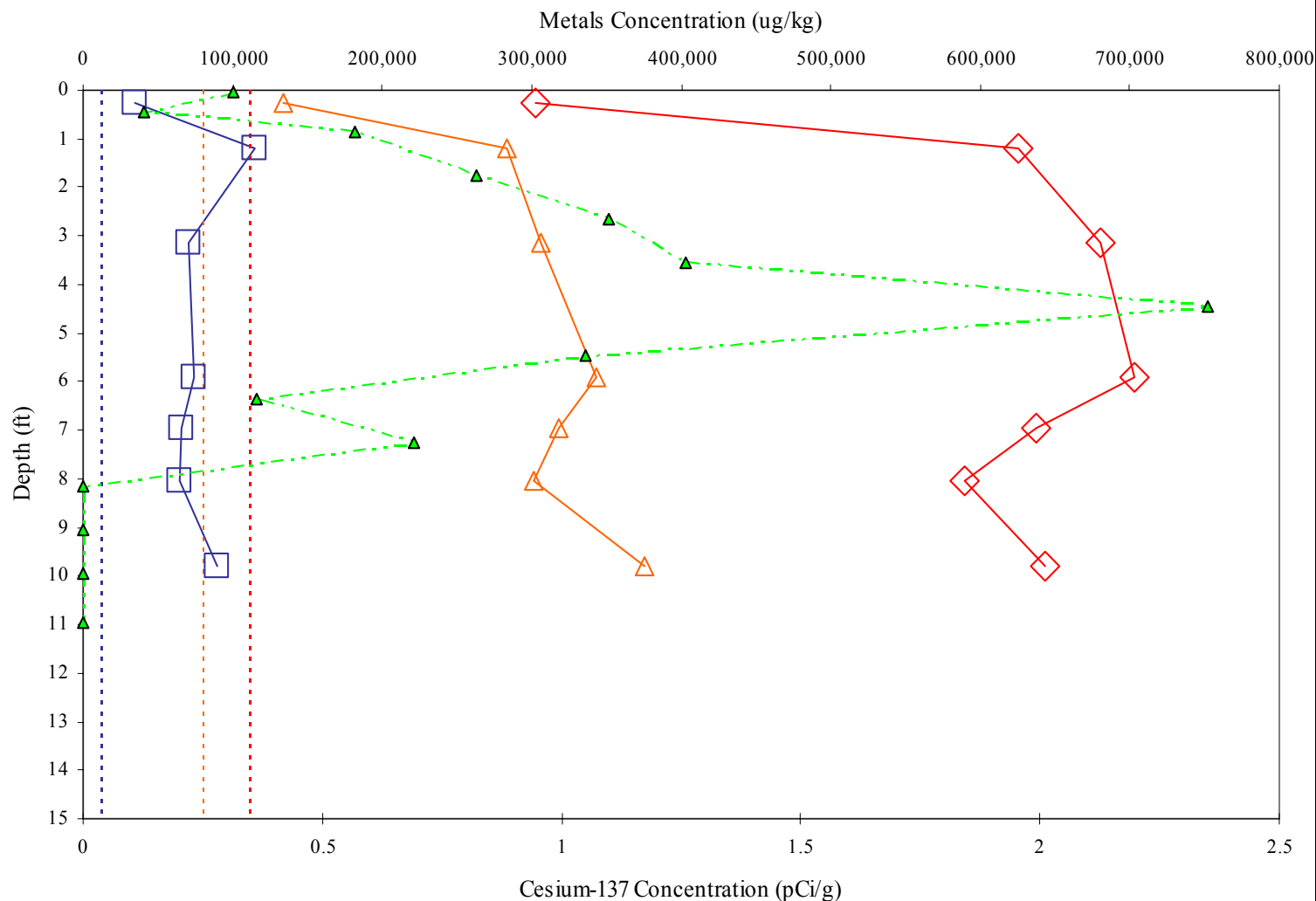
MALCOLM
PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Nickel, Barium, and Lead
(River Mile 3.1)
Lower Passaic River Restoration Project

Figure 4-11c

February 2006
Draft

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Nickel, Barium, and Lead
(River Mile 3.1)
Lower Passaic River Restoration Project

Figure 4-11d

February 2006
Draft

MALCOLM
PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Legend

- Nickel Detect
- Barium Detect
- Lead Detect
- Nickel Background
- Barium Background
- Lead Background
- Cesium-137

Location

May 1995, River Mile 3.3
TSI Location 232

Note:
Metals background concentrations
were taken from Sanders, P.F.,May 2003.
"Ambient Levels of Metals in New Jersey
Soils."

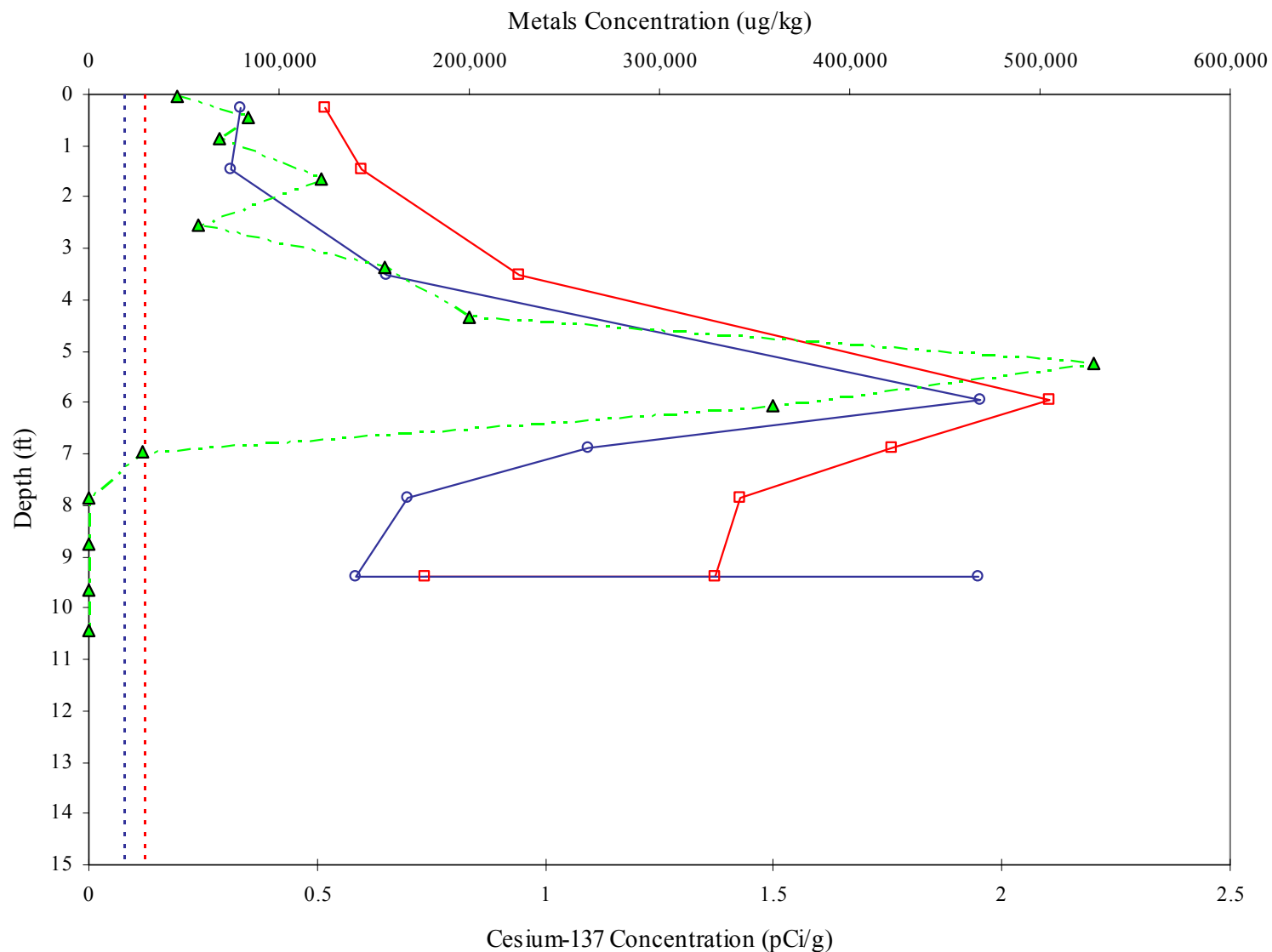Available online: http://www.state.nj.us/
dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Nickel, Barium, and Lead
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-11e

February 2006
Draft

MALCOLM
PIRNIE

Metals Concentration (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Downcore Profile for Nickel, Barium, and Lead
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-11f

February 2006
Draft
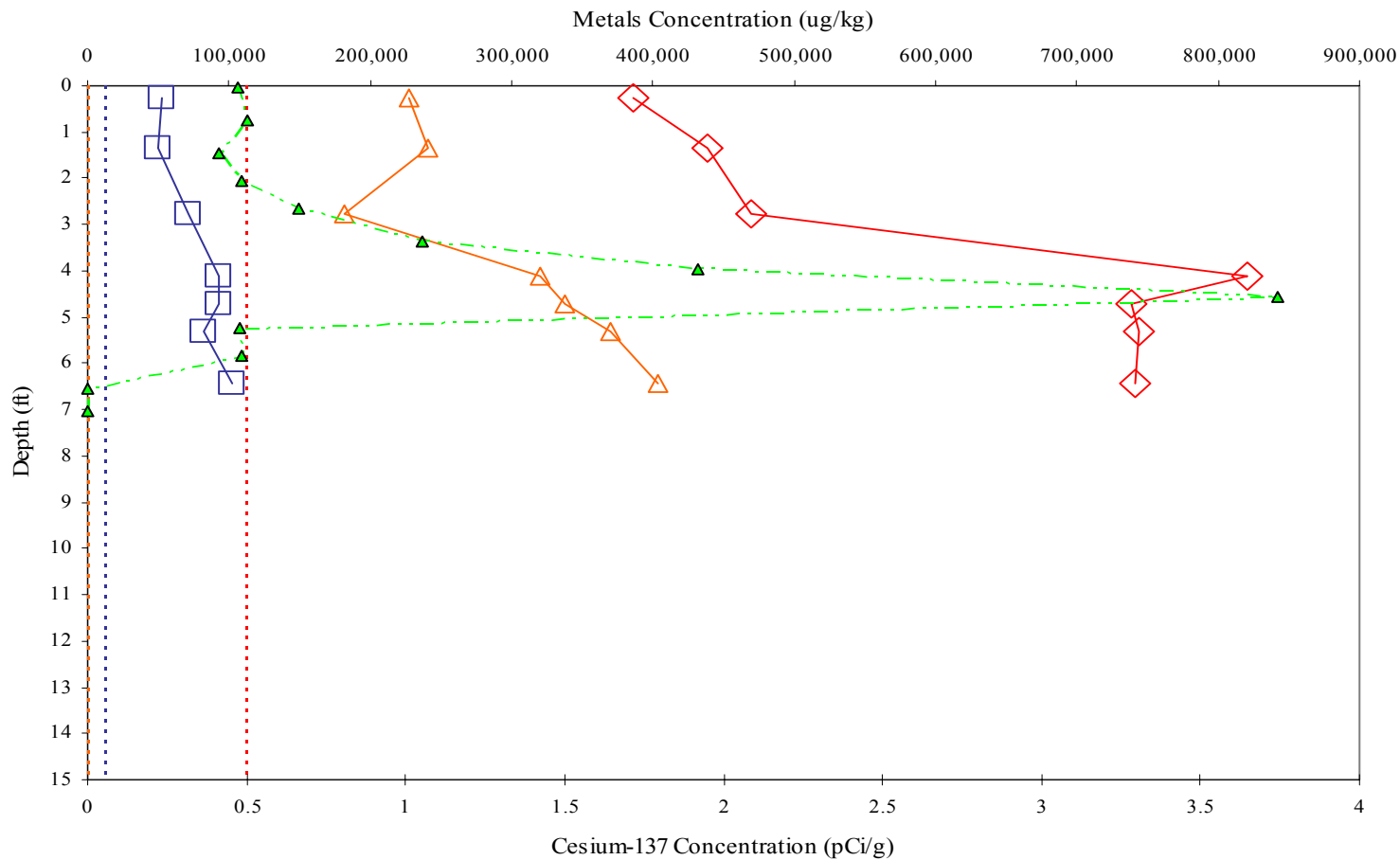
US Army Corps
of Engineers®

MALCOLM
PIRNIE

Downcore Profile for Nickel, Barium, and Lead
(River Mile 3.6)
Lower Passaic River Restoration Project

Figure 4-11g

February 2006
Draft
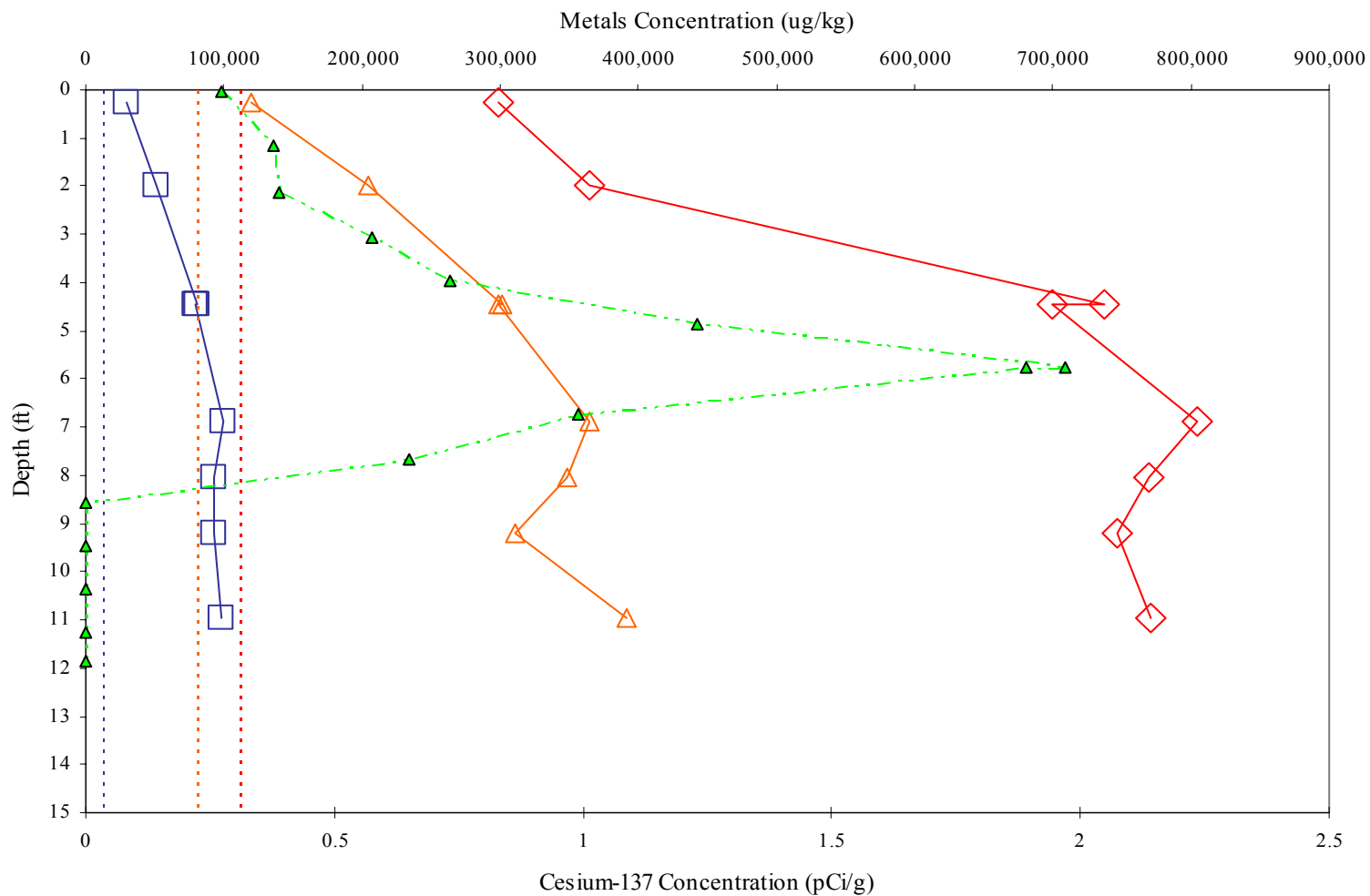
Metals Concentration (ug/kg)

Legend

- Nickel Detect
- Barium Detect
- Lead Detect
- Nickel Background
- Barium Background
- Lead Background
- Cesium-137

Location

May 1995, River Mile 4.0
TSI Location 241

Note:
Metals background concentrations
were taken from Sanders, P.F.,May 2003.
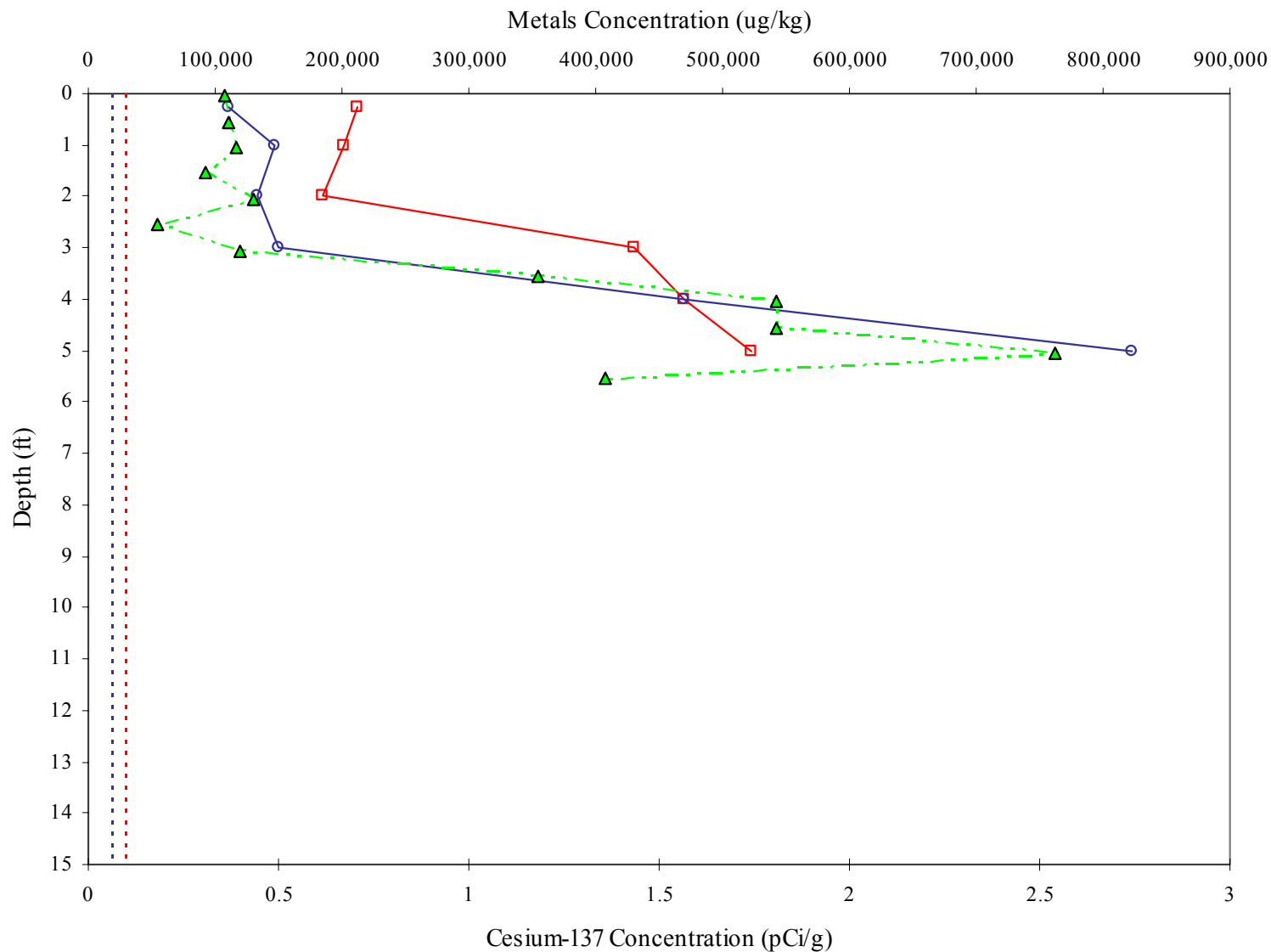"Ambient Levels of Metals in New Jersey
Soils."

Available online: http://www.state.nj.us/
dep/dsr/research/ambient-levels-metal.pdf

Cesium-137 Concentration (pCi/g)

Downcore Profile for Nickel, Barium, and Lead
(River Mile 4.0)
Lower Passaic River Restoration Project

Figure 4-11h

February 2006
Draft
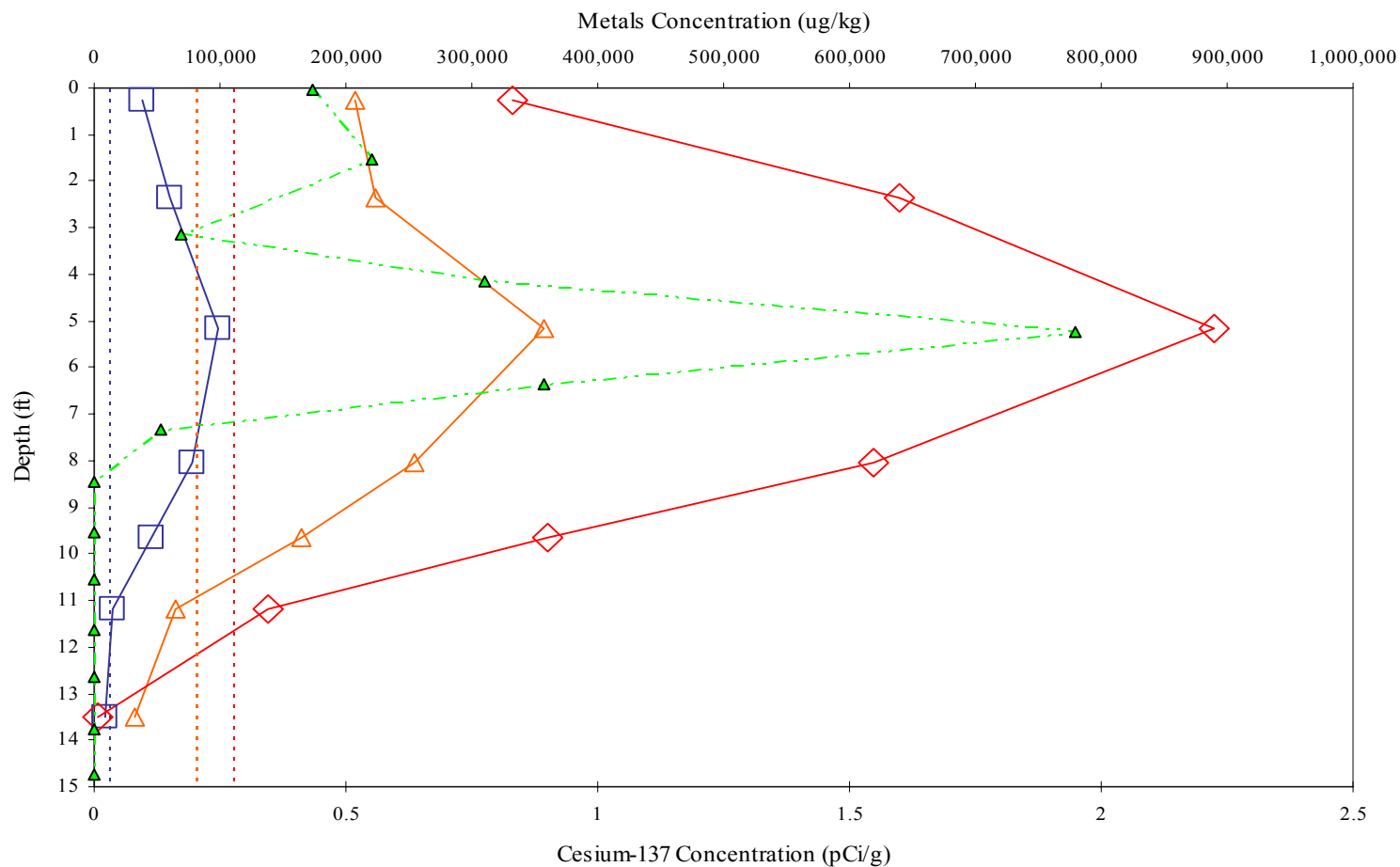
Metals Concentration (ug/kg)

Legend

Legend
□— Nickel Detect
△— Barium Detect
◇— Lead Detect
······· Nickel Background
······· Barium Background
······· Lead Background
—·—·— Cesium-137
······· Lead Background
—·—·— Cesium-137

Location

May 1995, River Mile 4.5
TSI Location 248

Note:
Metals background concentrations
were taken from Sanders, P.F.,May 2003.
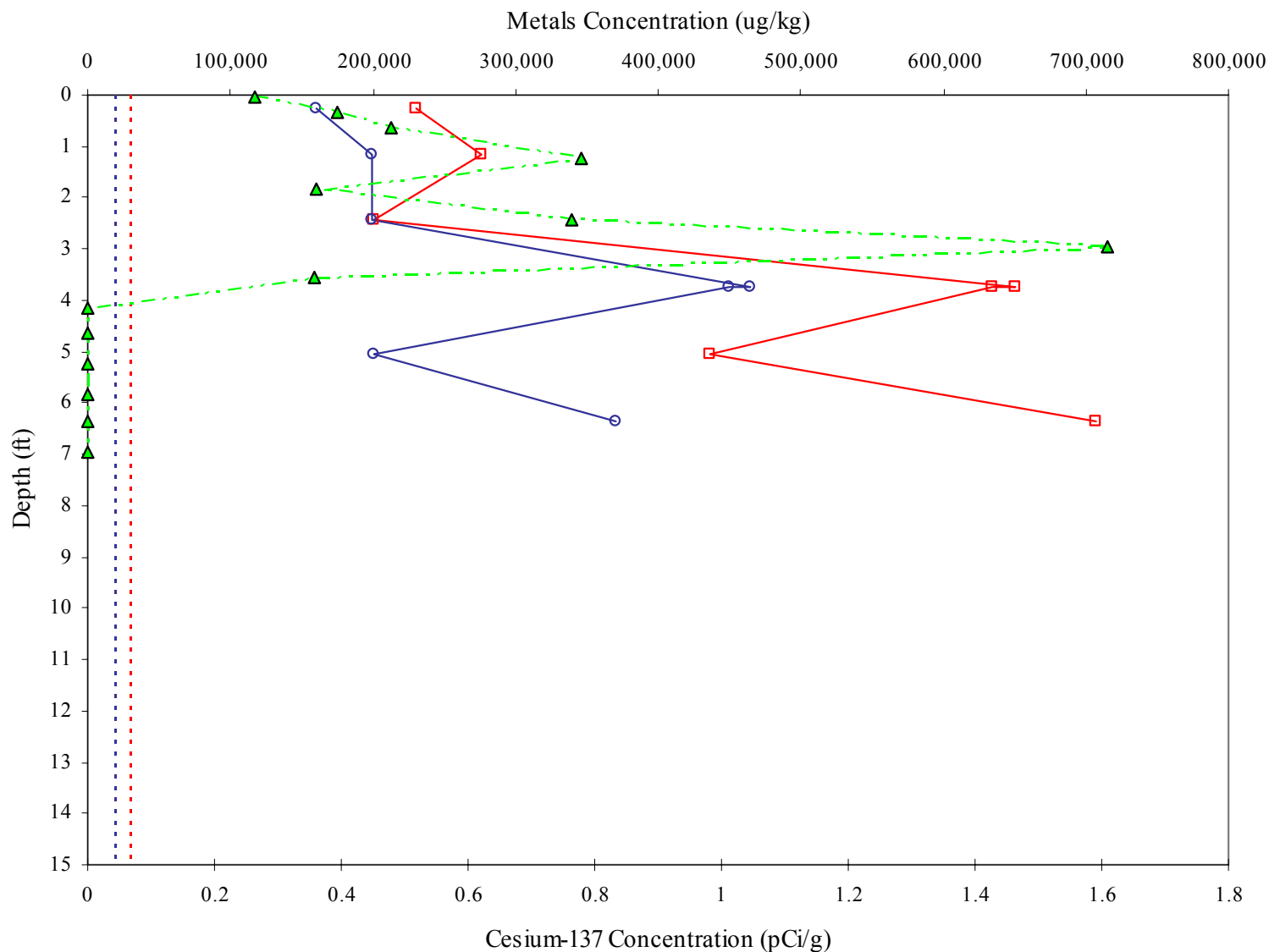"Ambient Levels of Metals in New Jersey
 Soils."

Available online: http://www.state.nj.us/
dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Nickel, Barium, and Lead
(River Mile 4.5)
Lower Passaic River Restoration Project

Figure 4-11i

February 2006
Draft

MALCOLM
PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)
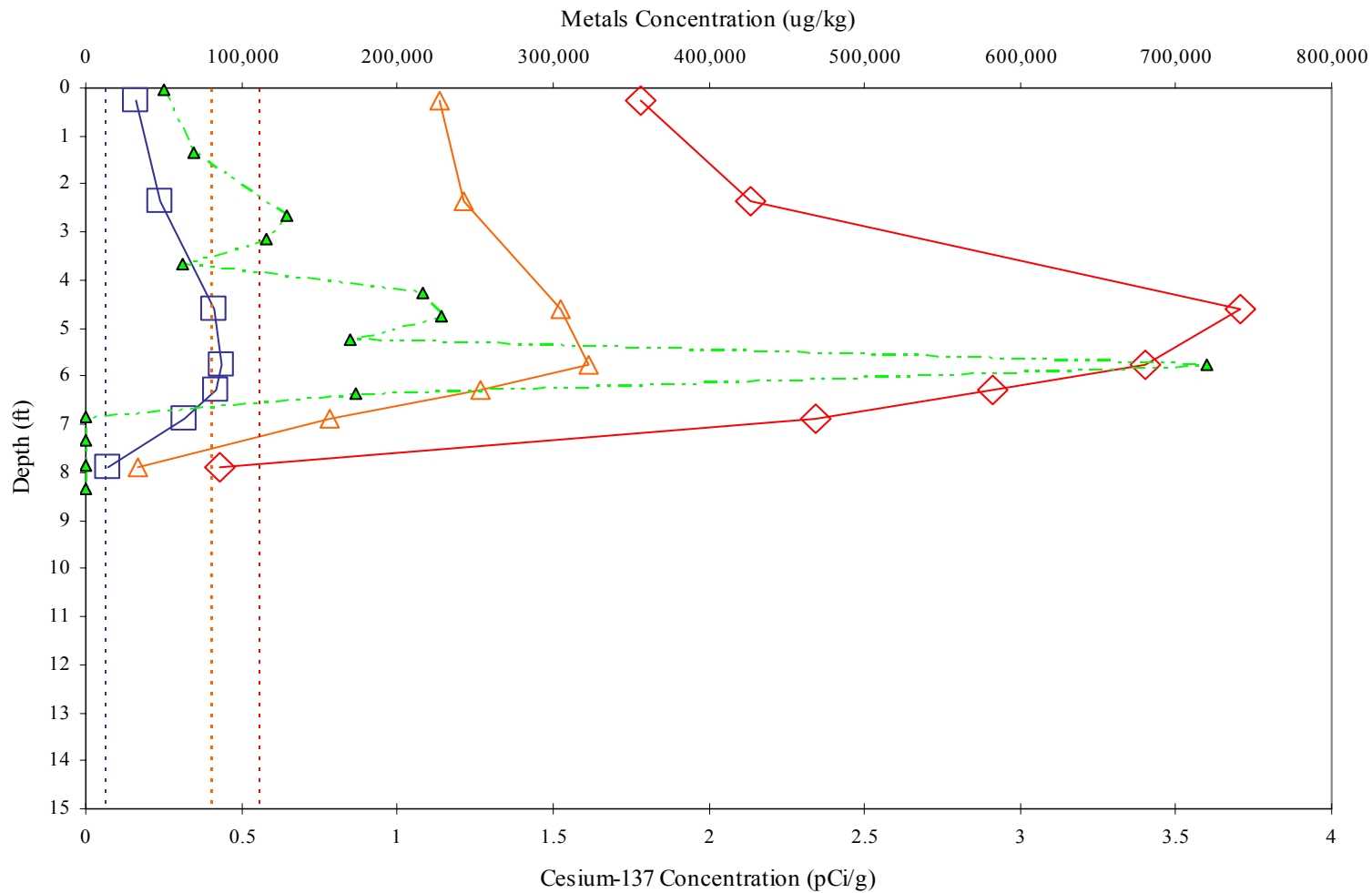
Location

May 1995, River Mile 4.7
TSI Location 251

Note:
Metals background concentrations
were taken from Sanders, P.F.,May 2003.
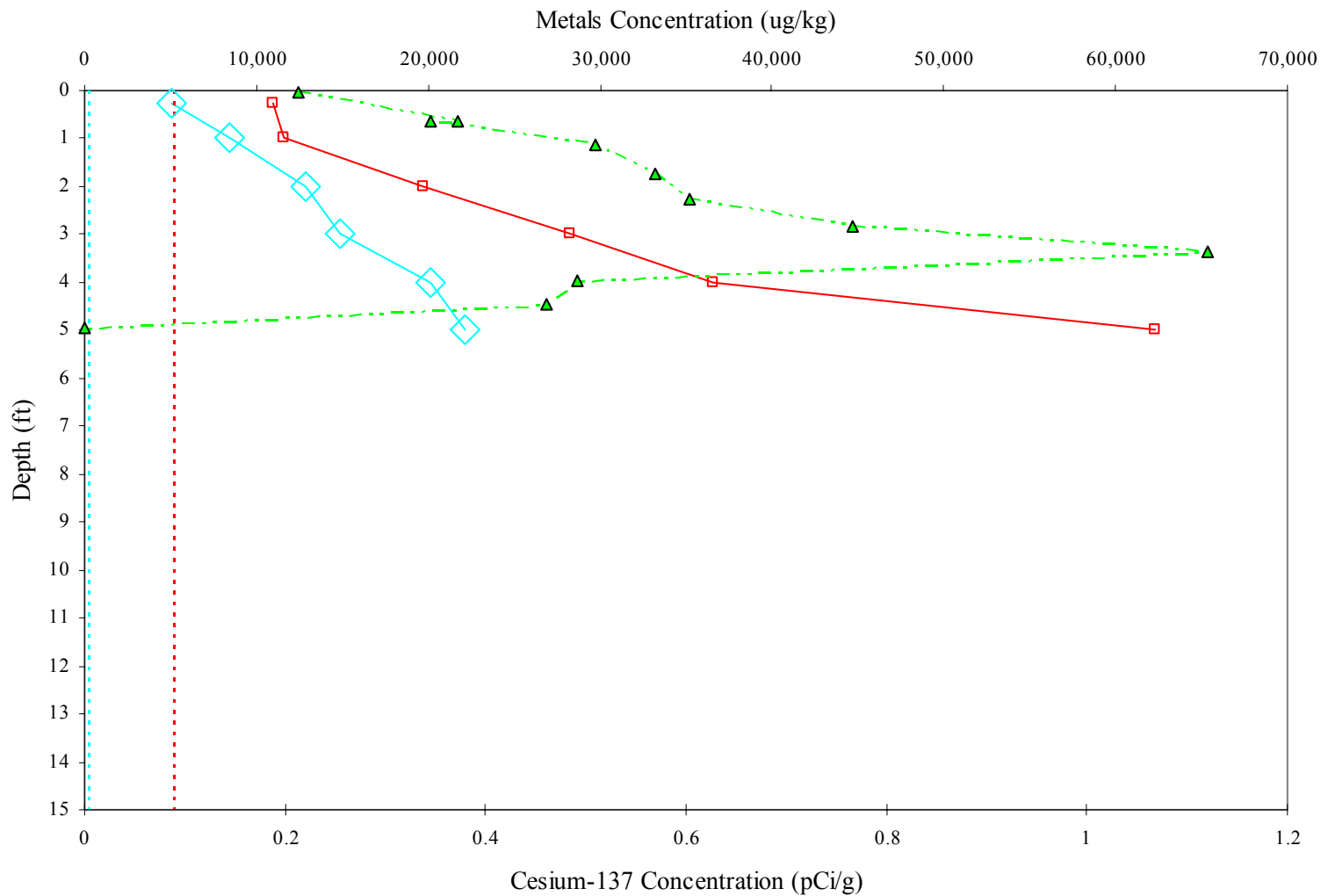"Ambient Levels of Metals in New Jersey
Soils."

Available online: http://www.state.nj.us/
dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Nickel, Barium, and Lead
(River Mile 4.7)
Lower Passaic River Restoration Project

Figure 4-11j

February 2006
Draft
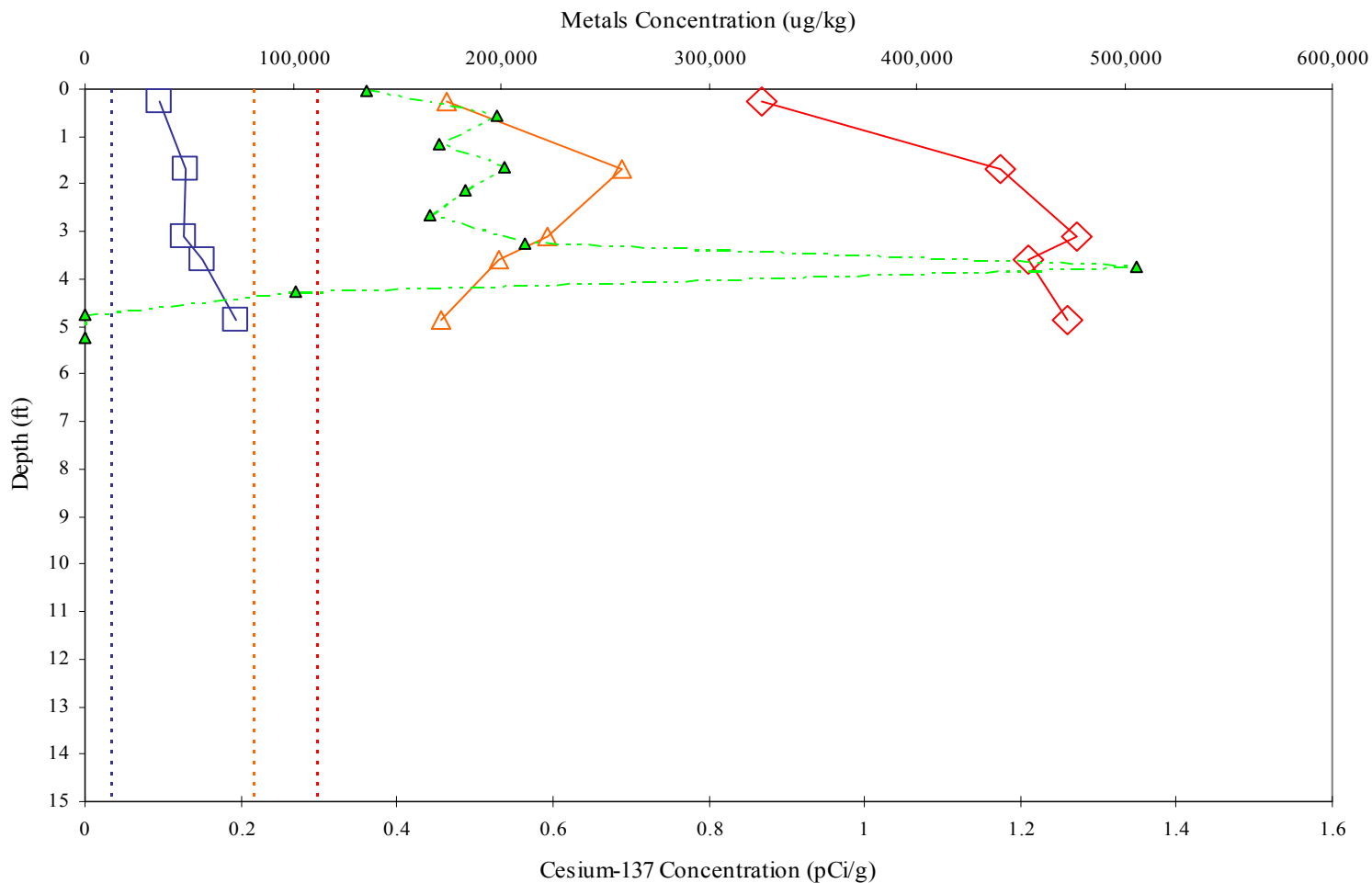
MALCOLM
PIRNIE

Legend

- Nickel Detect
- Barium Detect
- Lead Detect
- Nickel Background
- Barium Background
- Lead Background
- Cesium-137

Location

May1995, River Mile 4.9
TSI Location 253

Note:
Metals background concentrations
were taken from Sanders, P.F.,May 2003.
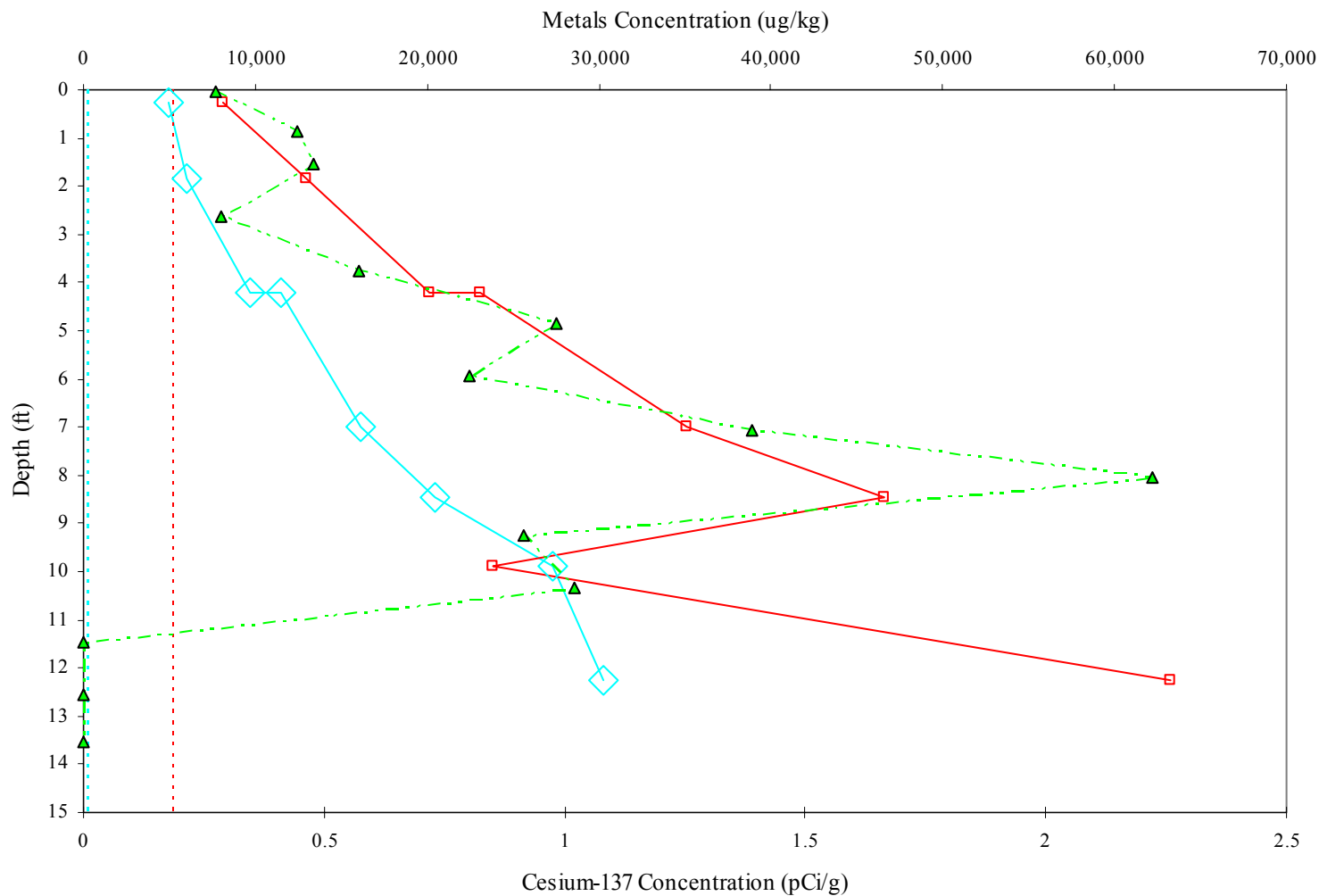"Ambient Levels of Metals in New Jersey
Soils."

Available online: http://www.state.nj.us/
dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Nickel, Barium, and Lead
(River Mile 4.9)

Lower Passaic River Restoration Project

Figure 4-11k

February 2006
Draft
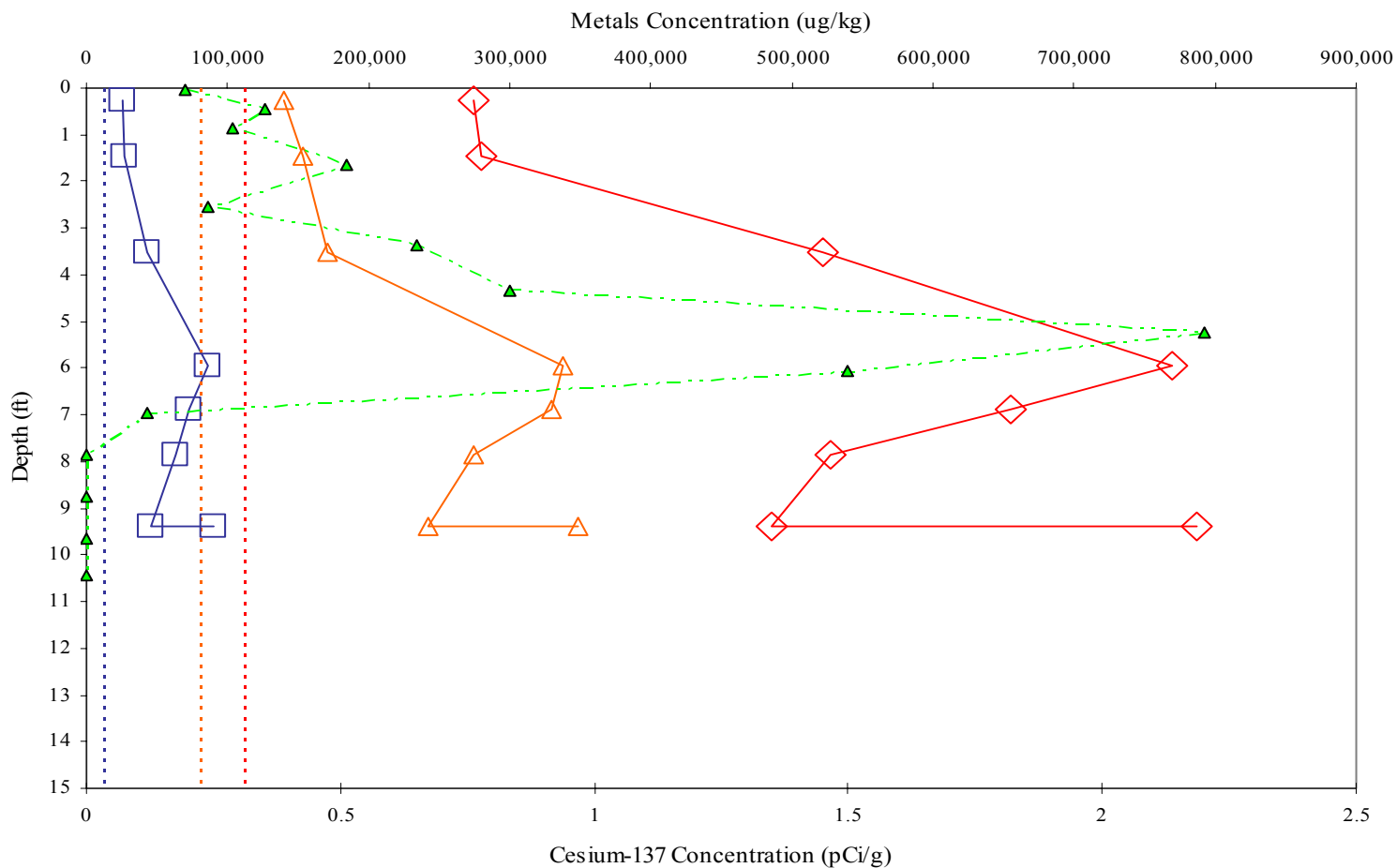
Metals Concentration (ug/kg)

Location

May 1995, River Mile 6.3
TSI Location 272

Note:
Metals background concentrations
were taken from Sanders, P.F.,May 2003.
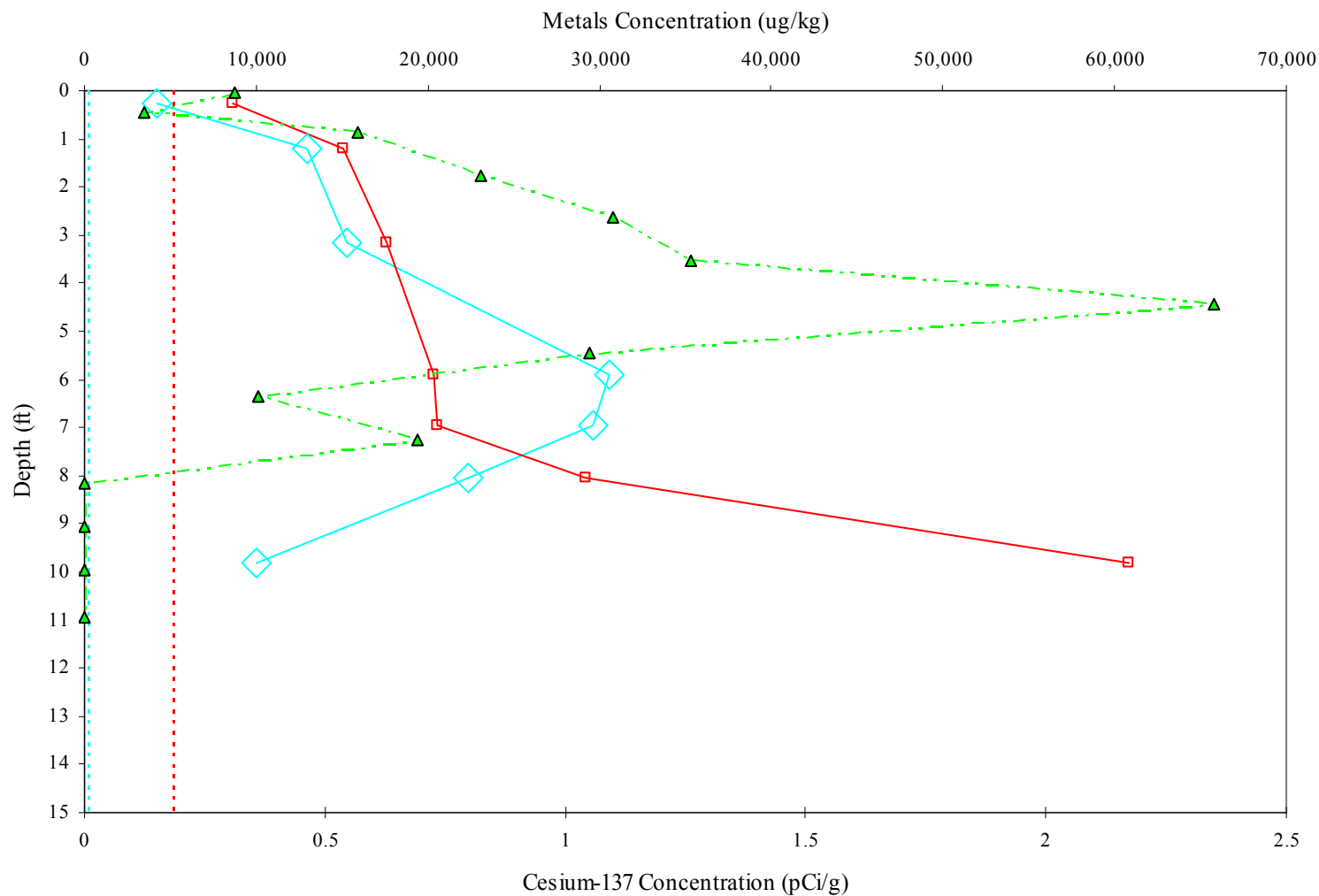"Ambient Levels of Metals in New Jersey
Soils."

Available online: http://www.state.nj.us/
dep/dsr/research/ambient-levels-metal.pdf

Depth (ft)

Cesium-137 Concentration (pCi/g)

Downcore Profile for Nickel, Barium, and Lead
(River Mile 6.3)
Lower Passaic River Restoration Project
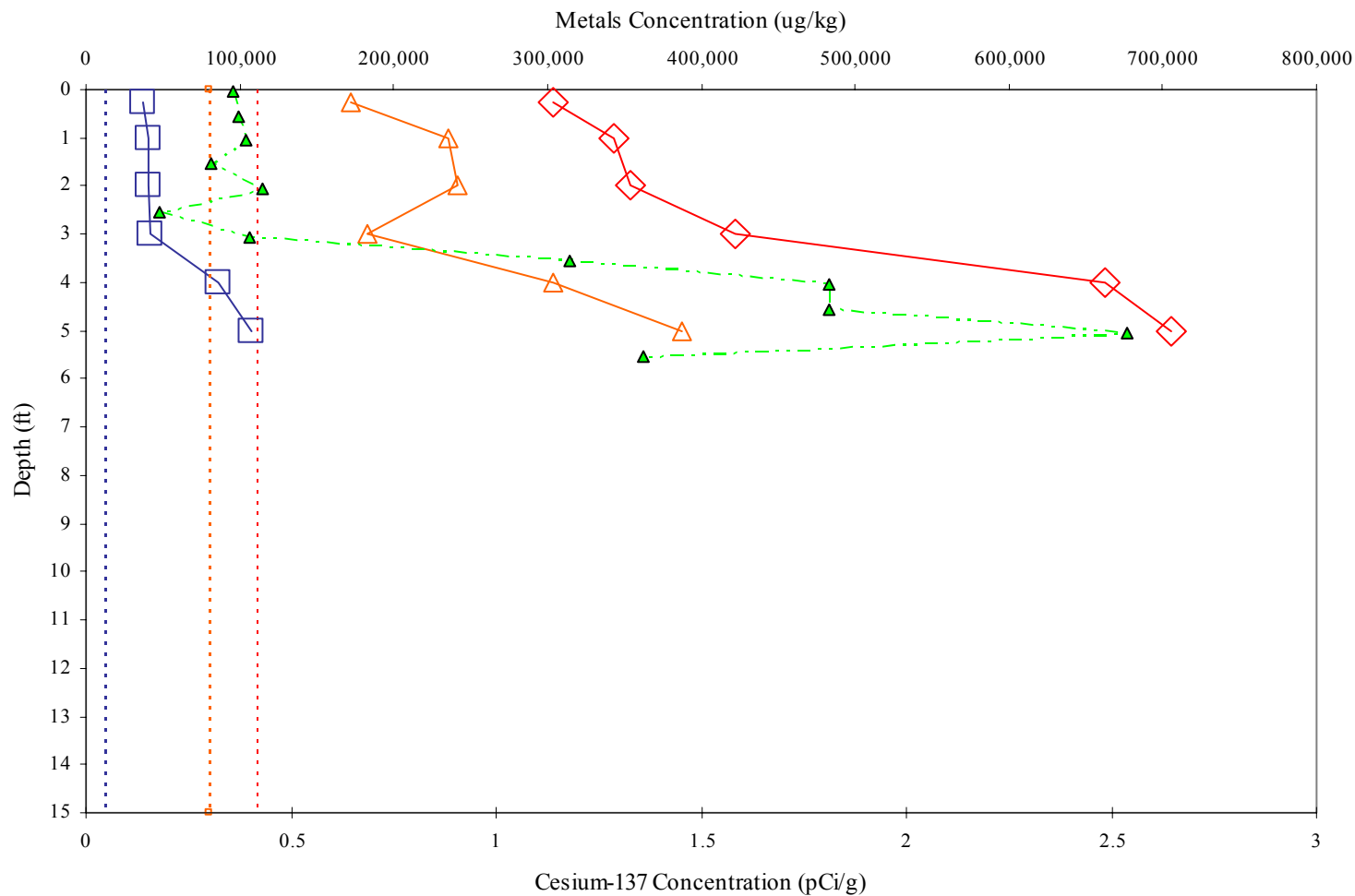
Figure 4-11I

February 2006
Draft

MALCOLM
PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Nickel, Barium, and Lead
(River Mile 6.4)
Lower Passaic River Restoration Project

Figure 4-11m

February 2006
Draft
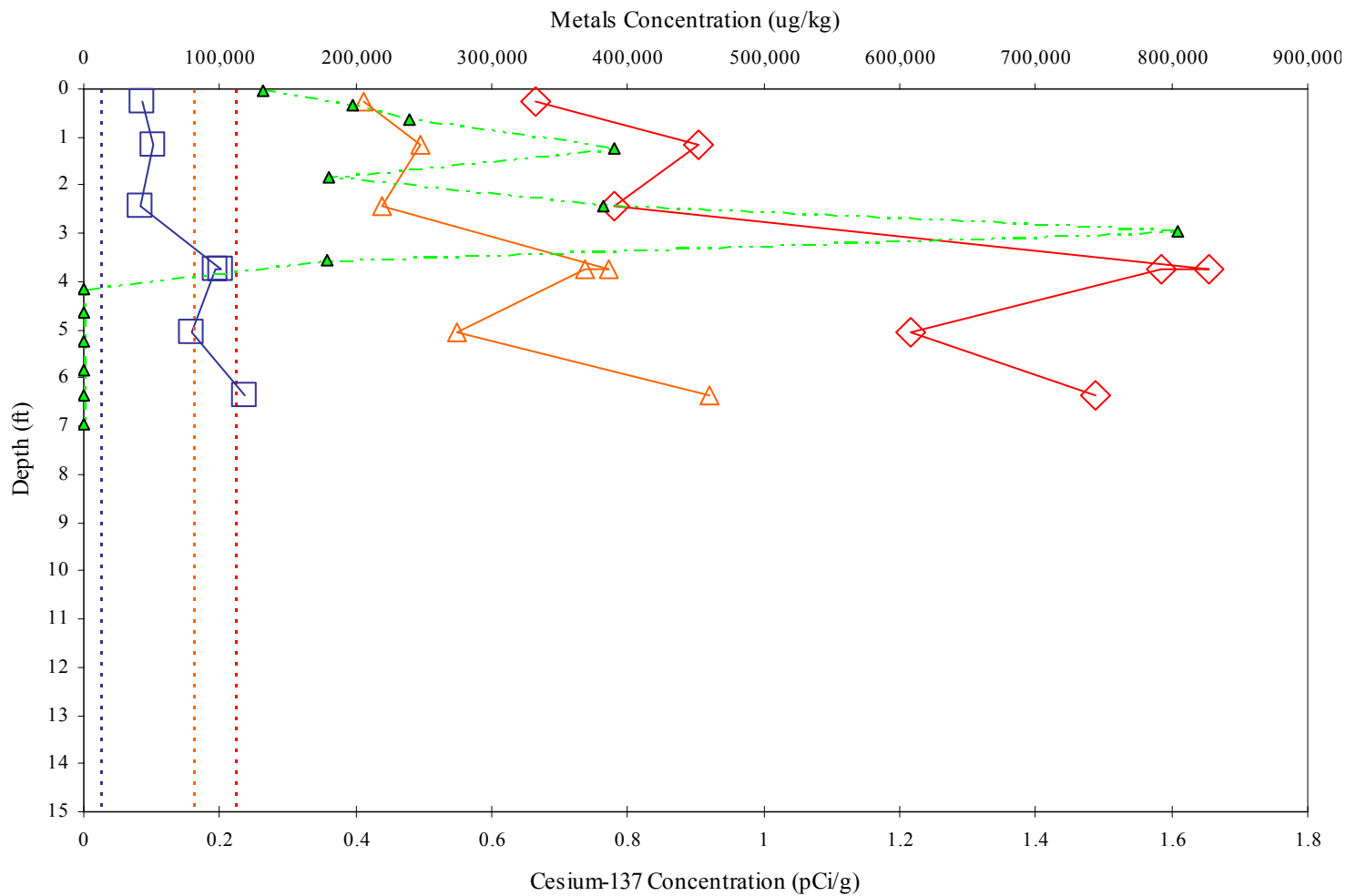
MALCOLM
PIRNIE

Legend

- Nickel Detect
- Barium Detect
- Lead Detect
- Nickel Background
- Barium Background
- Lead Background
- Cesium-137

Location

June 1995, River Mile 6.5
TSI Location 275

Note:
Metals background concentrations
were taken from Sanders, P.F.,May 2003.
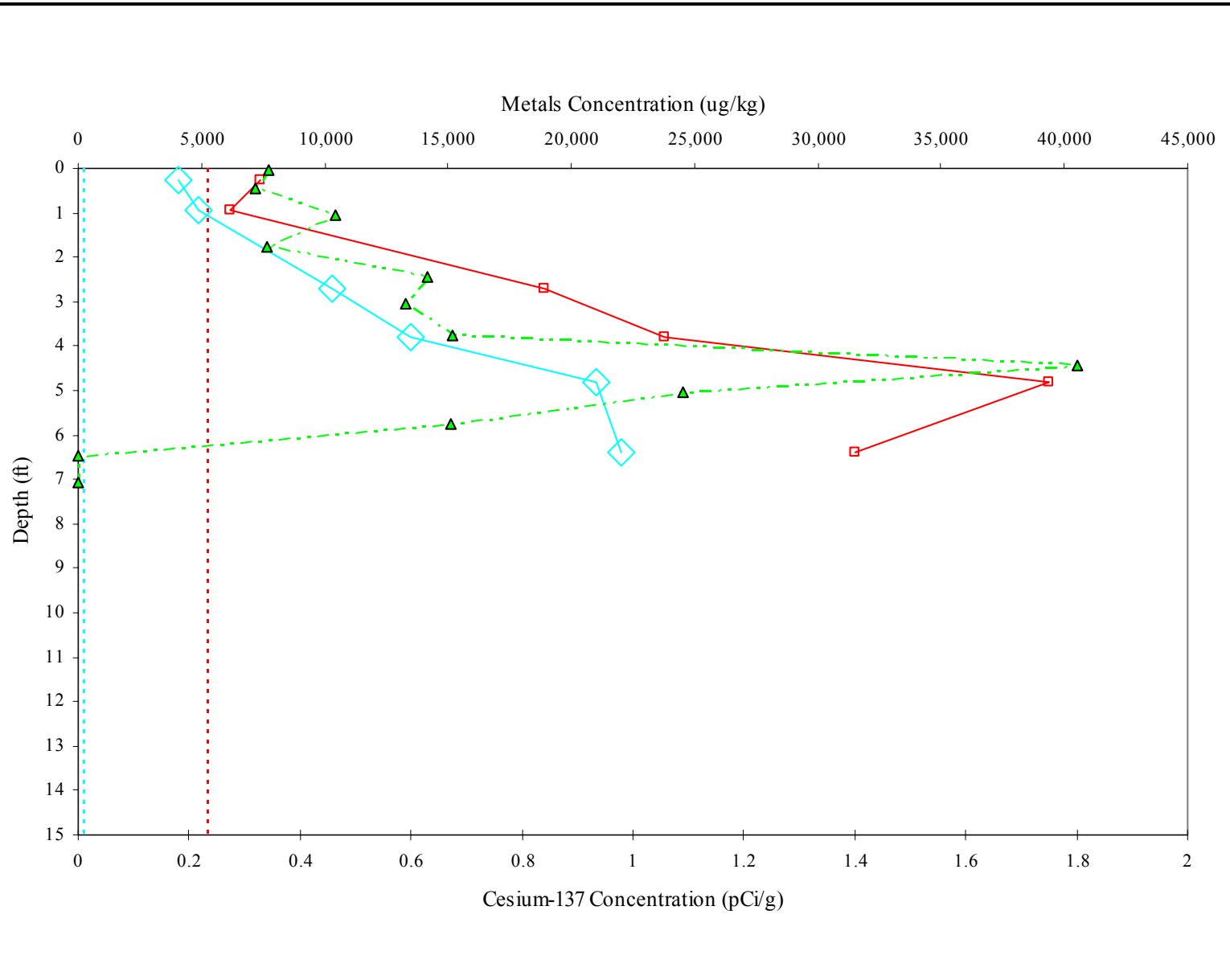"Ambient Levels of Metals in New Jersey
Soils."

Available online: http://www.state.nj.us/
dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Nickel, Barium, and Lead
(River Mile 6.5)
Lower Passaic River Restoration Project

Figure 4-11n

February 2006
Draft
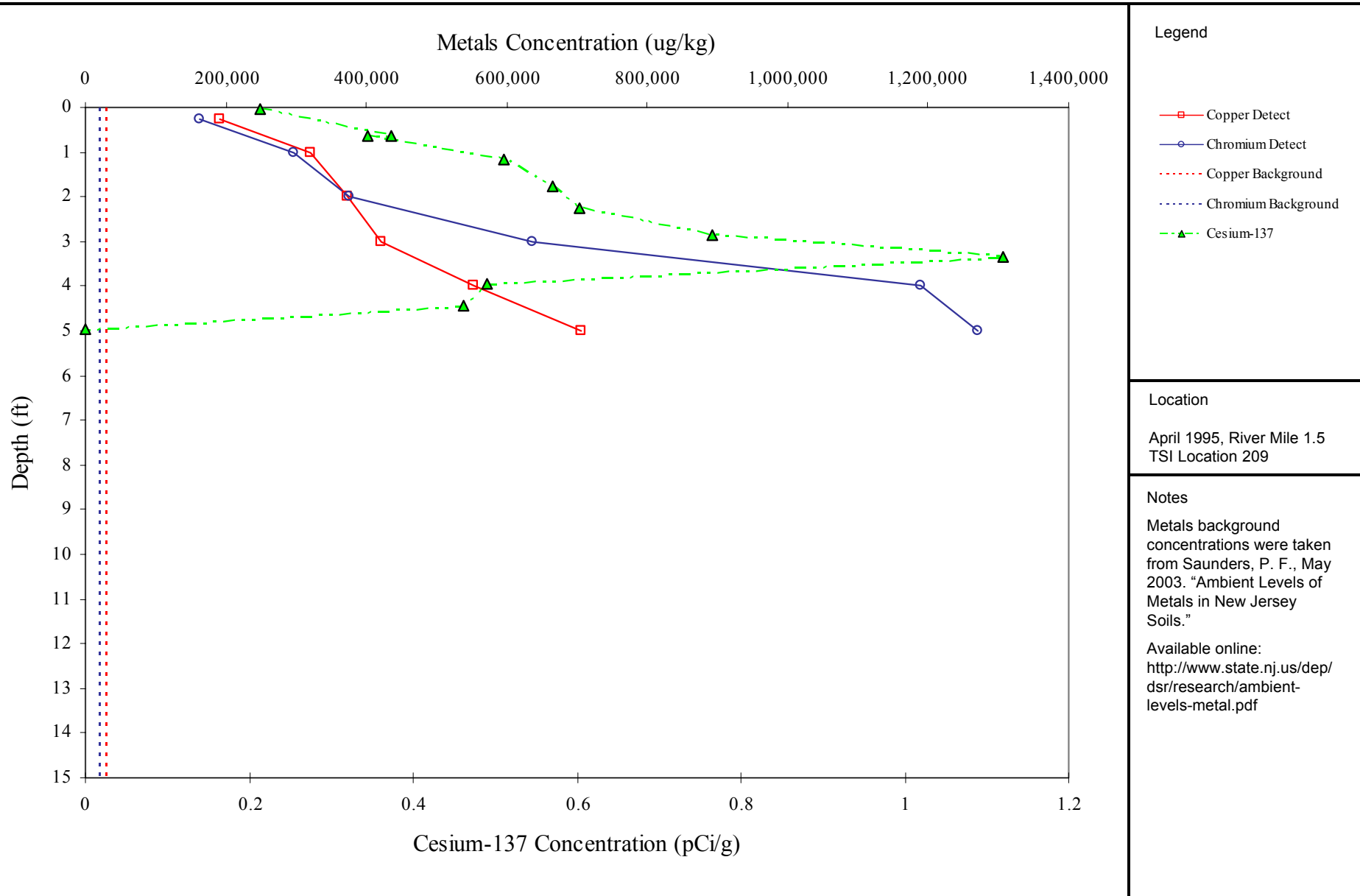
Downcore Profile for Copper and Chromium
(River Mile 1.5)
Lower Passaic River Restoration Project

Figure 4-12a

February 2006
Draft
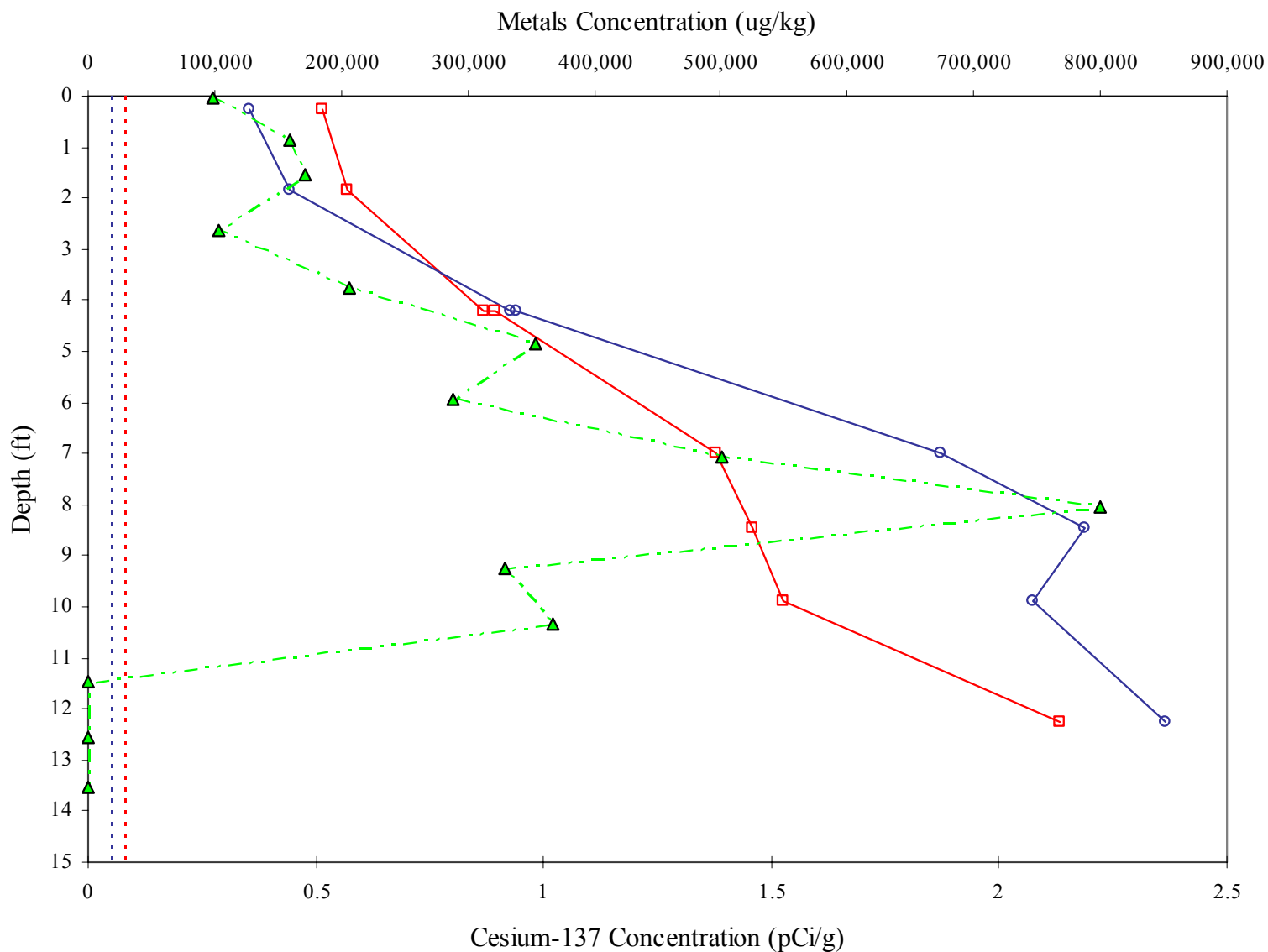
Downcore Profile for Copper and Chromium
(River Mile 2.7)
Lower Passaic River Restoration Project

Figure 4-12b

February 2006
Draft
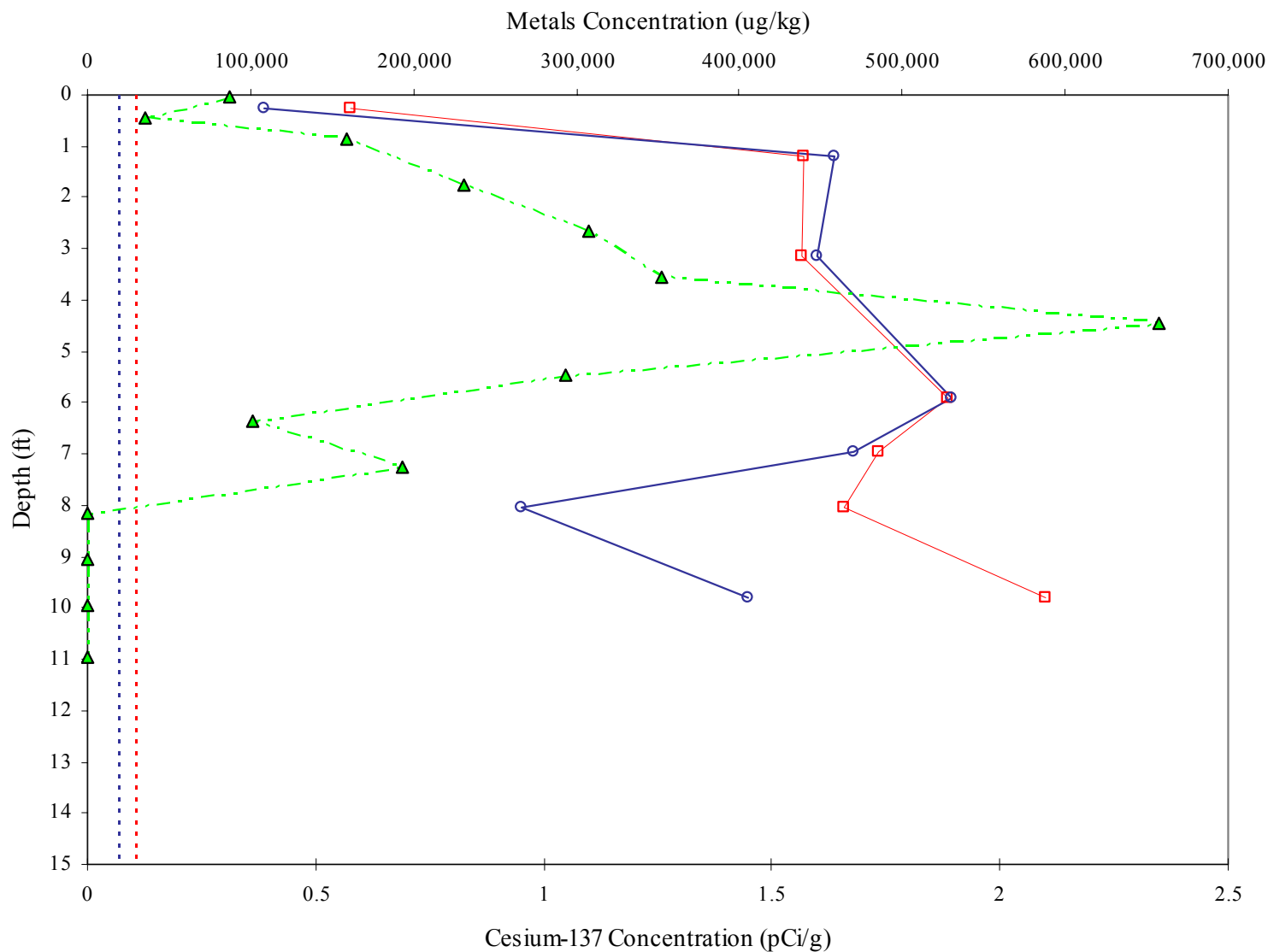
Legend

Copper Detect
Chromium Detect
Copper Background
Chromium Background
Cesium-137

Location

April 1995, River Mile 2.7
TSI Location 222

Notes

Metals background concentrations were taken from Saunders, P. F., May 2003. "Ambient Levels of Metals in New Jersey Soils."
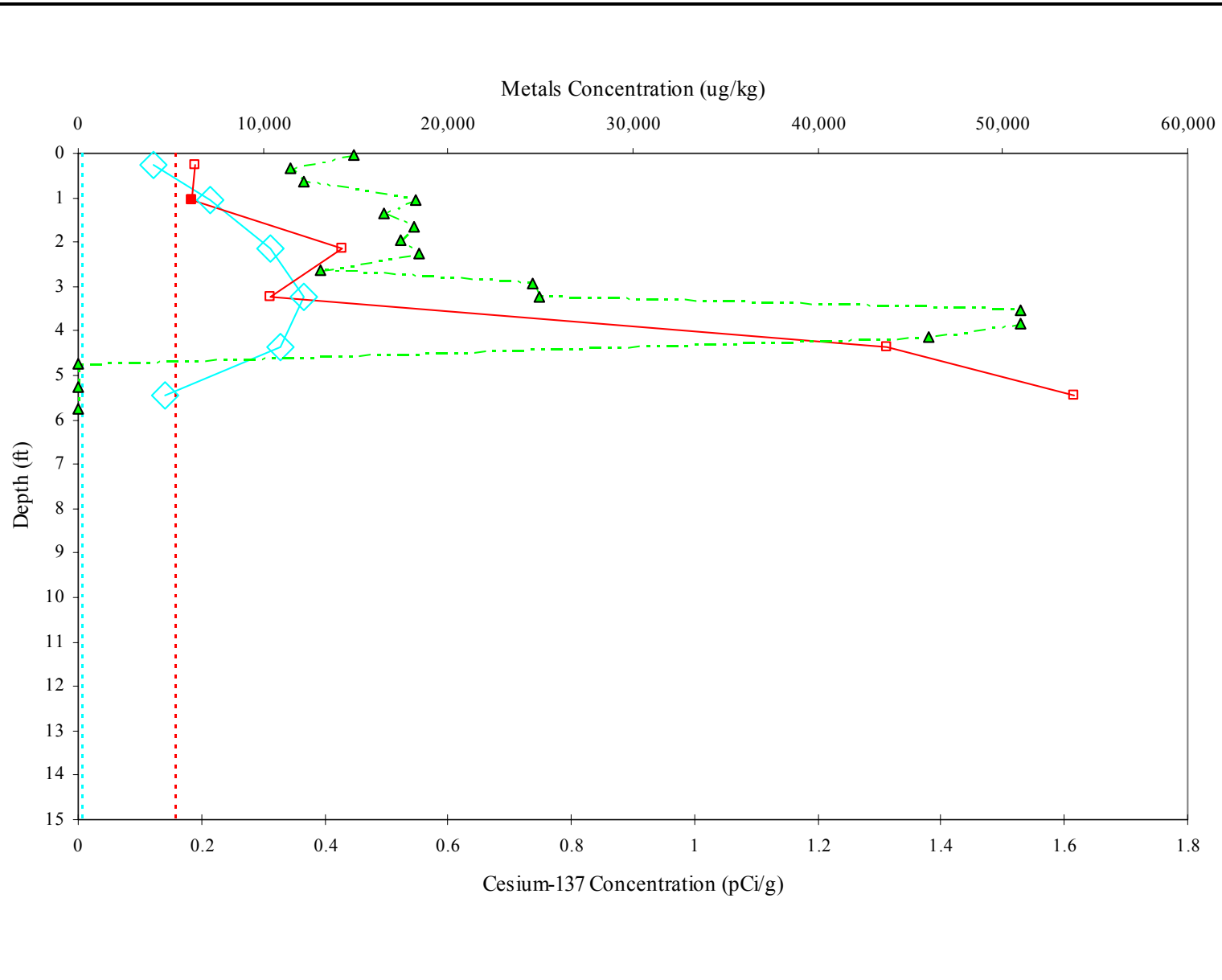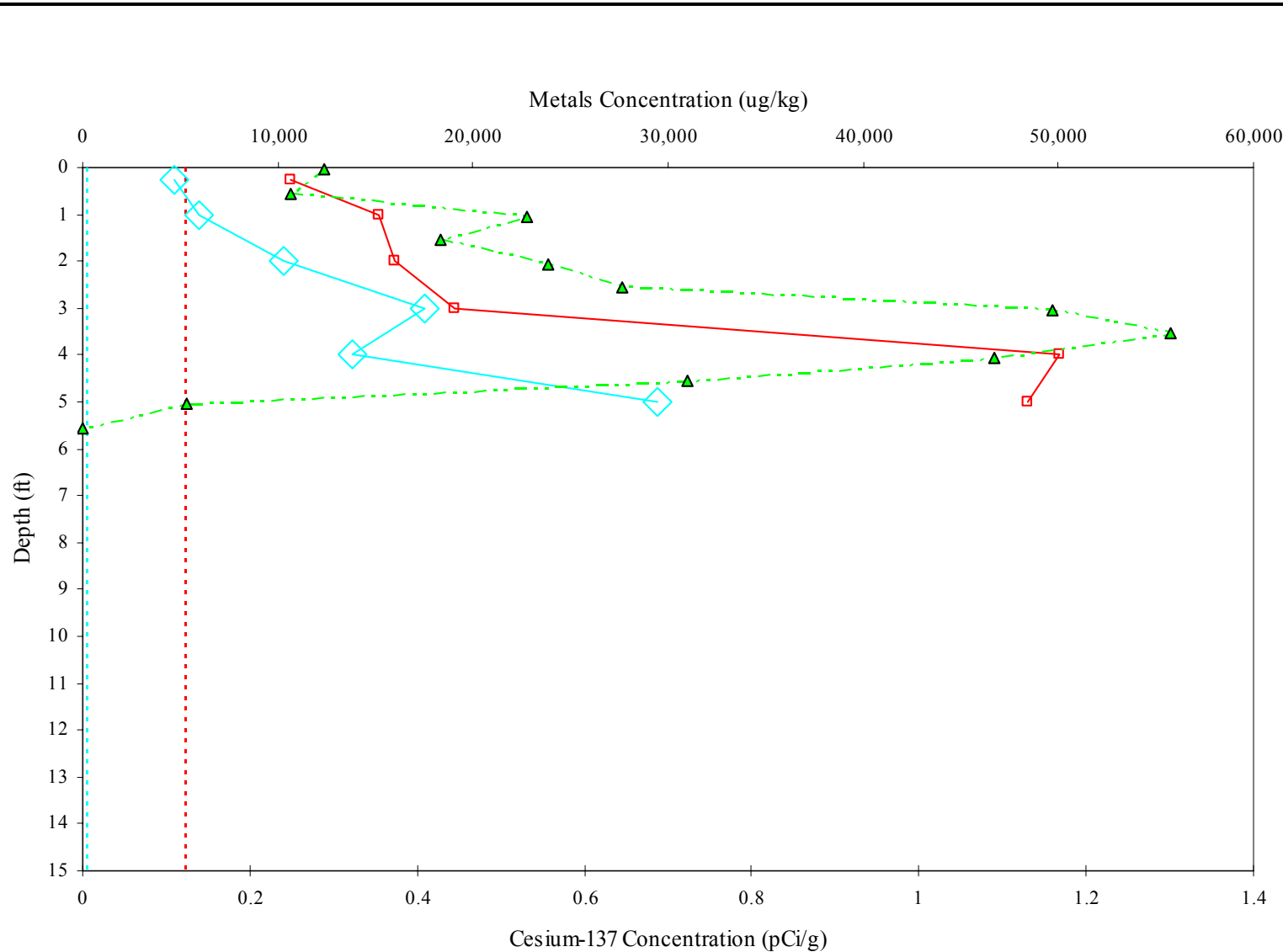
Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Metals Concentration (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Downcore Profile for Copper and Chromium
(River Mile 3.1)
Lower Passaic River Restoration Project

Figure 4-12c

February 2006
Draft
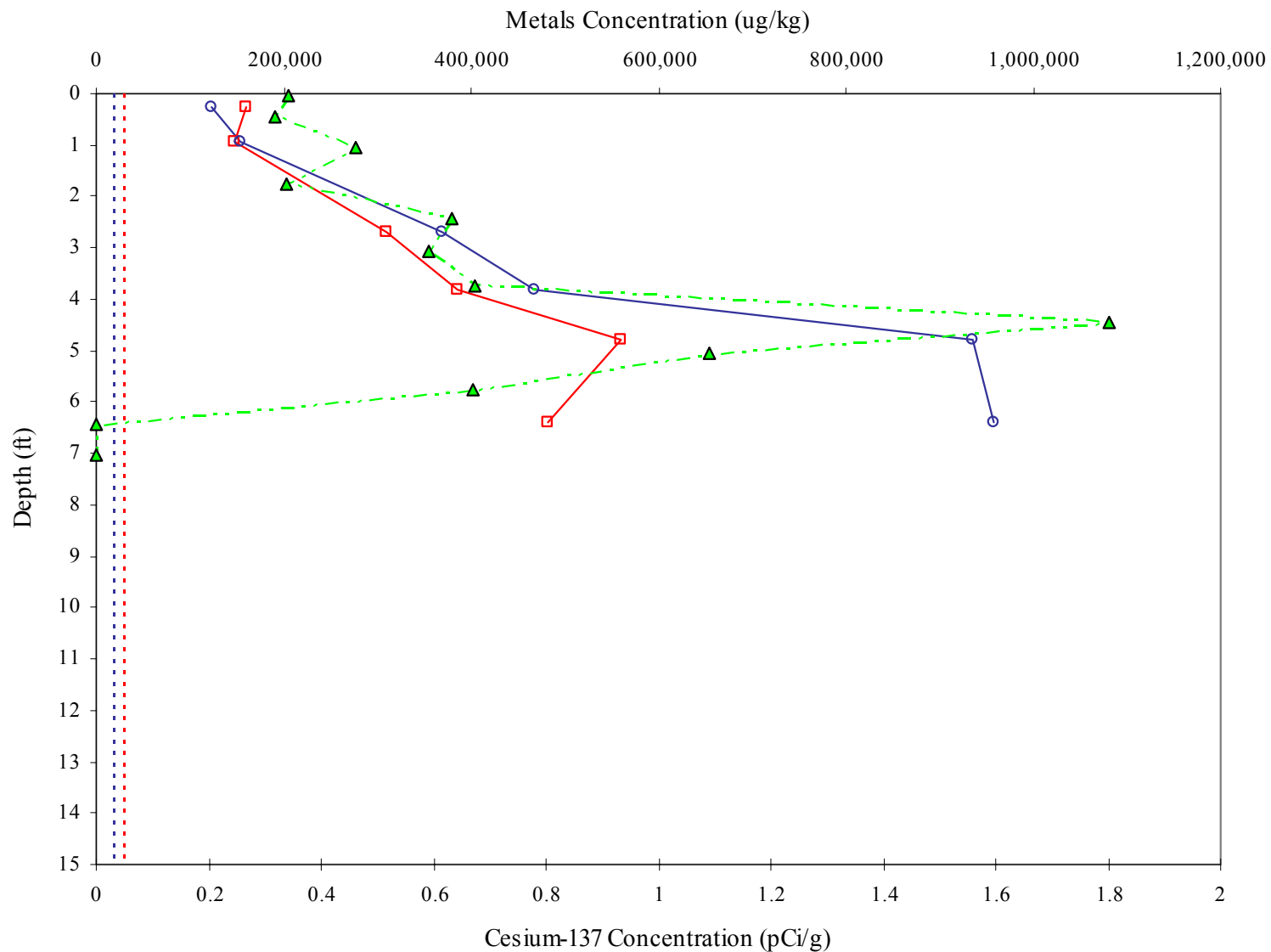
Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Copper and Chromium
(River Mile 3.1)
Lower Passaic River Restoration Project

Figure 4-12d

February 2006
Draft
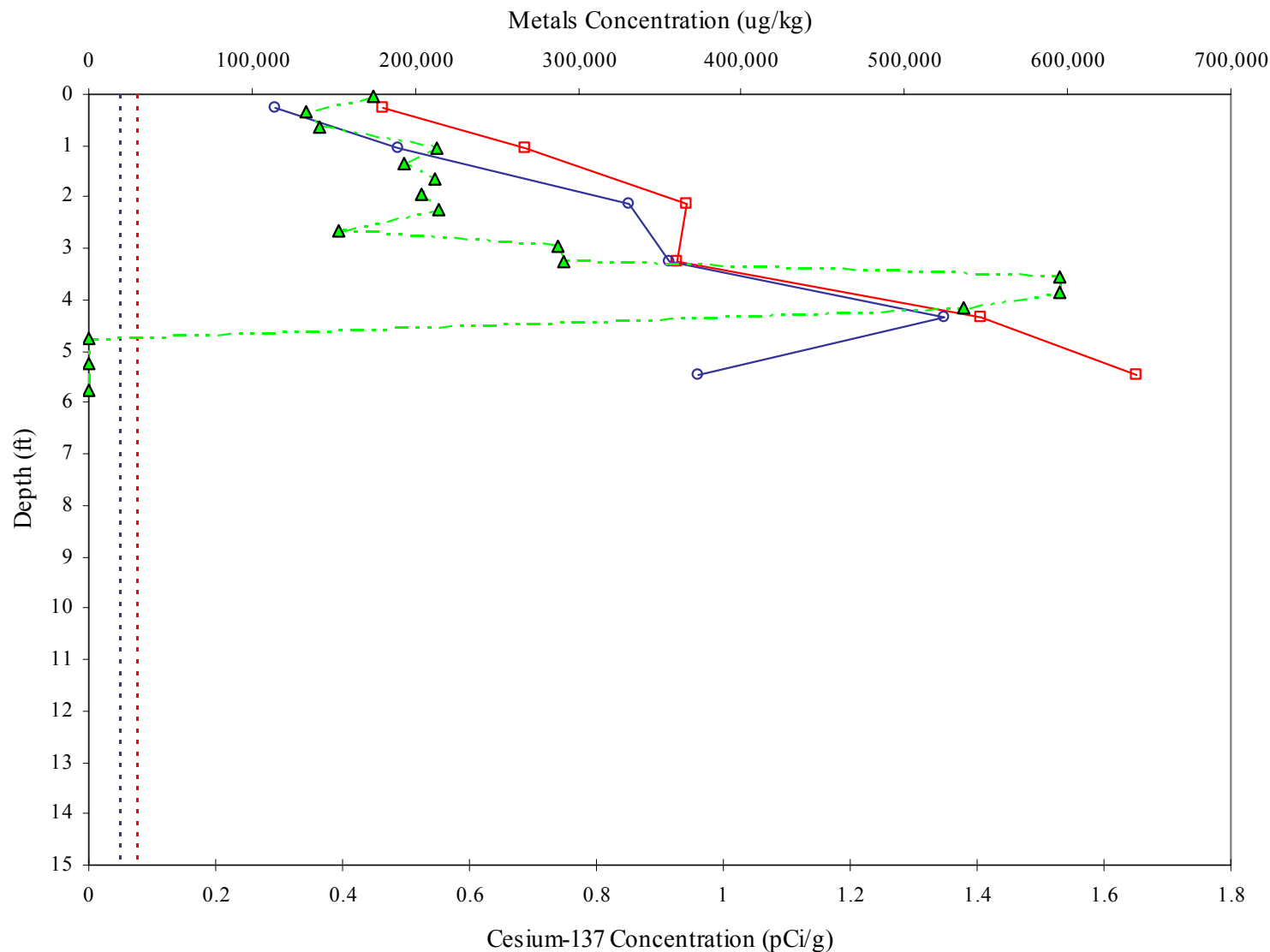
MALCOLM
PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Location

May 1995, River Mile 3.3
TSI Location 232

Notes

Metals background concentrations were taken from Saunders, P. F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Copper and Chromium
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-12e

February 2006
Draft
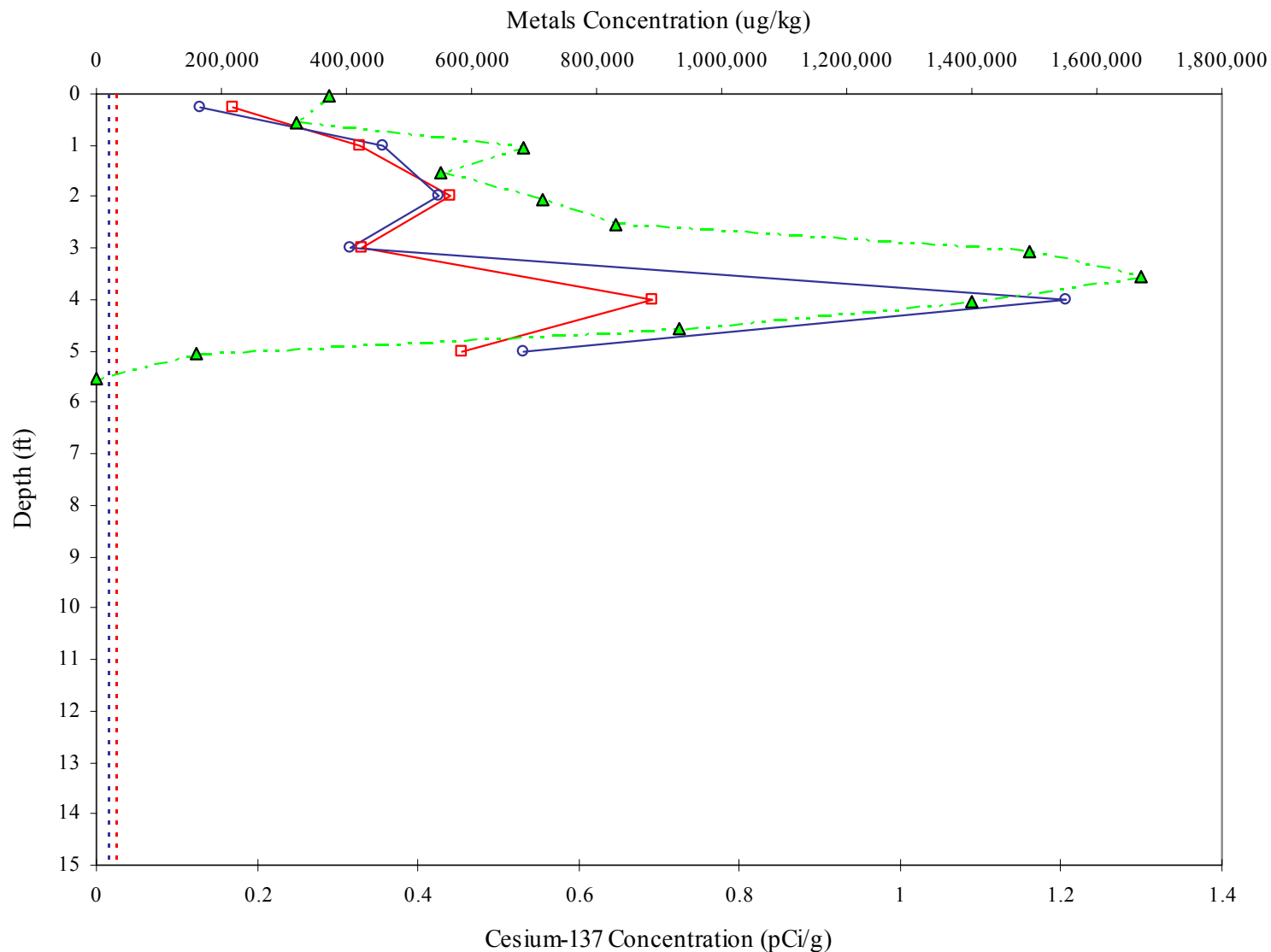
Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Copper and Chromium
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-12f

February 2006
Draft
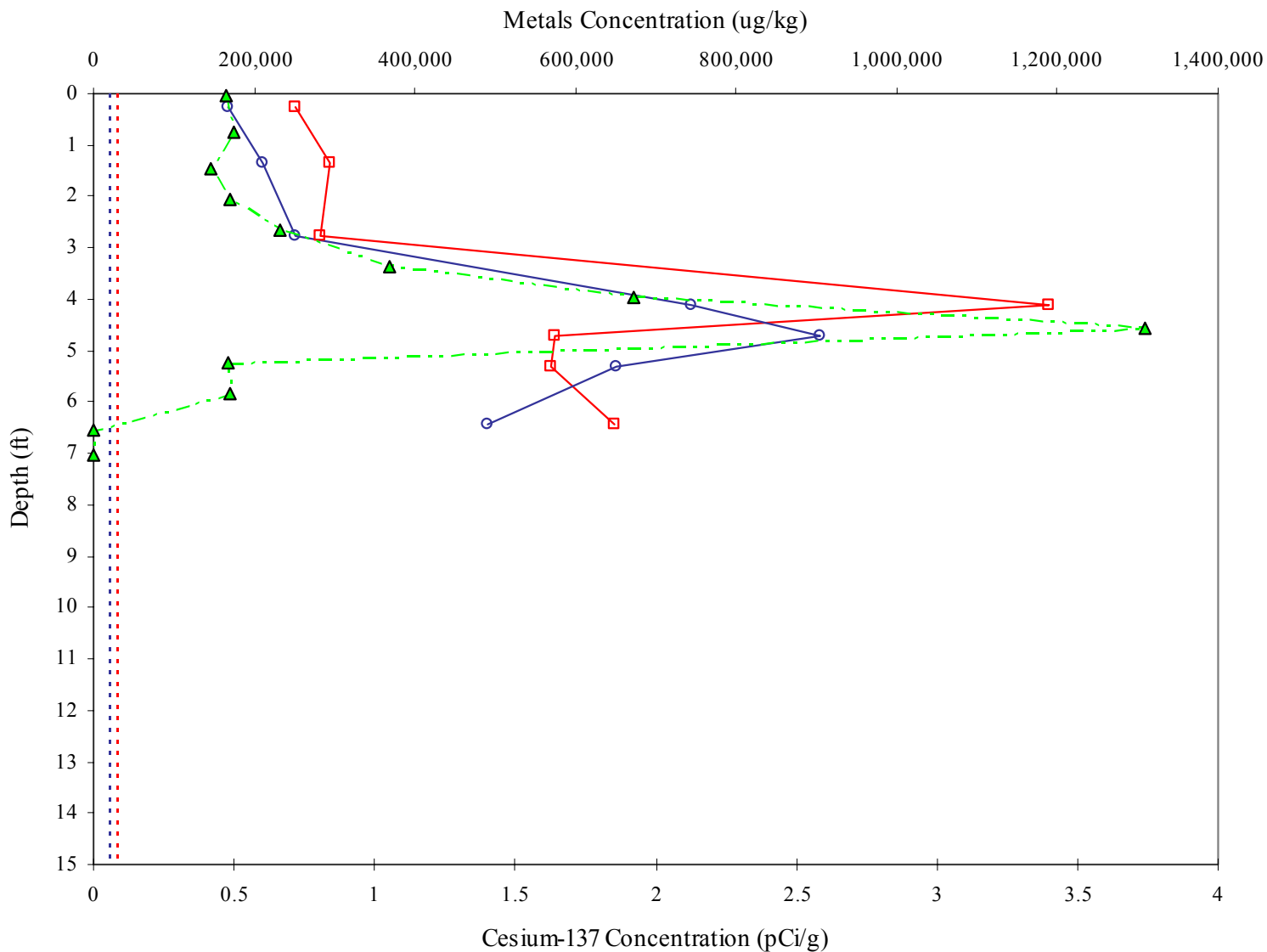
MALCOLM PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Downcore Profile for Copper and Chromium
(River Mile 3.6)
Lower Passaic River Restoration Project

Figure 4-12g

February 2006
Draft

Downcore Profile for Copper and Chromium
(River Mile 4.0)
Lower Passaic River Restoration Project

Figure 4-12h

February 2006
Draft

Downcore Profile for Copper and Chromium
(River Mile 4.5)
Lower Passaic River Restoration Project

Figure 4-12i

February 2006
Draft

Downcore Profile for Copper and Chromium
(River Mile 4.7)
Lower Passaic River Restoration Project

Figure 4-12j

February 2006
Draft
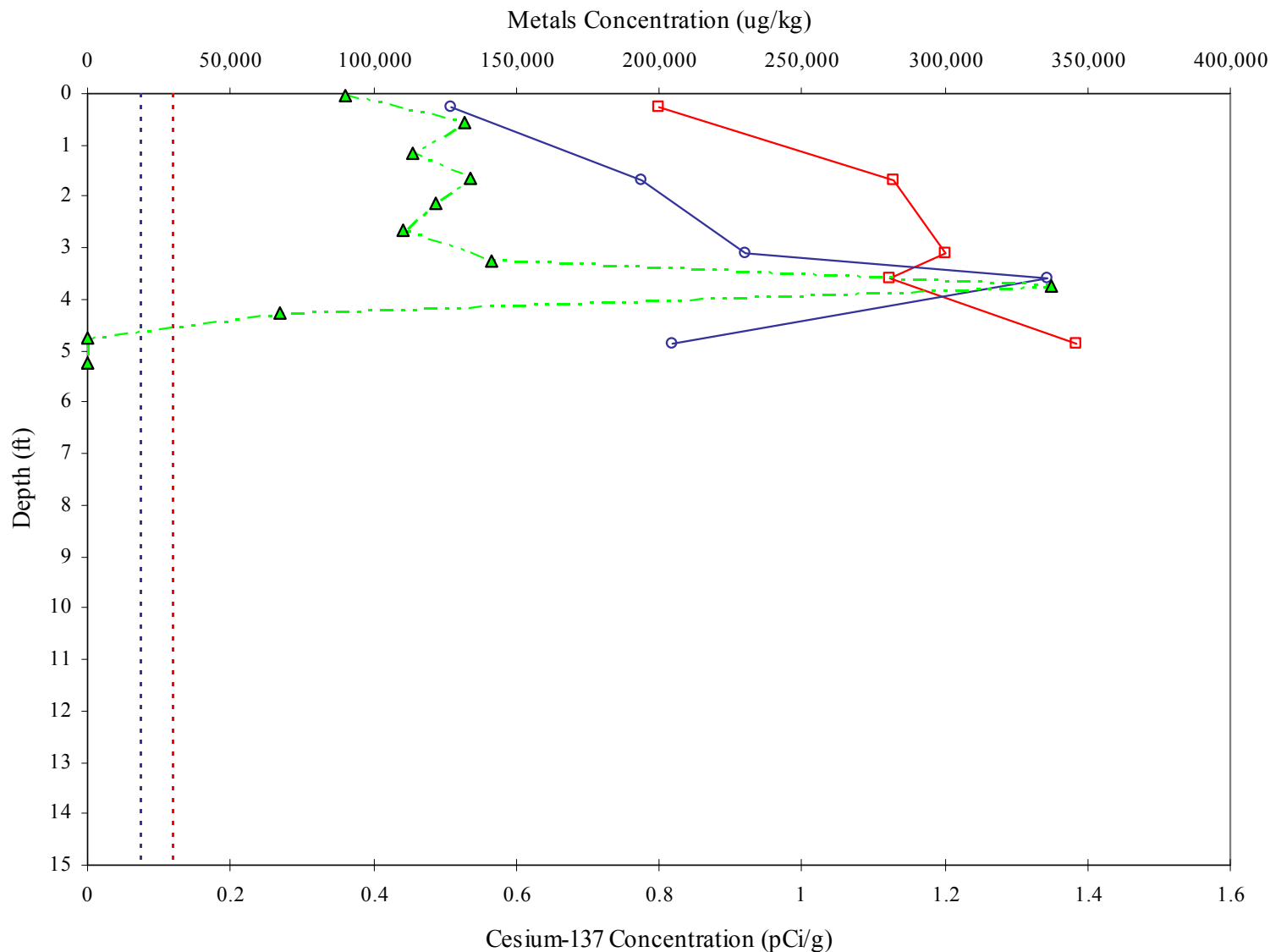
Metals Concentration (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Downcore Profile for Copper and Chromium
(River Mile 4.9)
Lower Passaic River Restoration Project

Figure 4-12k

February 2006
Draft

MALCOLM
PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Location

May 1995, River Mile 6.3
TSI Location 272

Notes

Metals background
concentrations were taken
from Saunders, P. F., May
2003. "Ambient Levels of
Metals in New Jersey
Soils."

Available online:
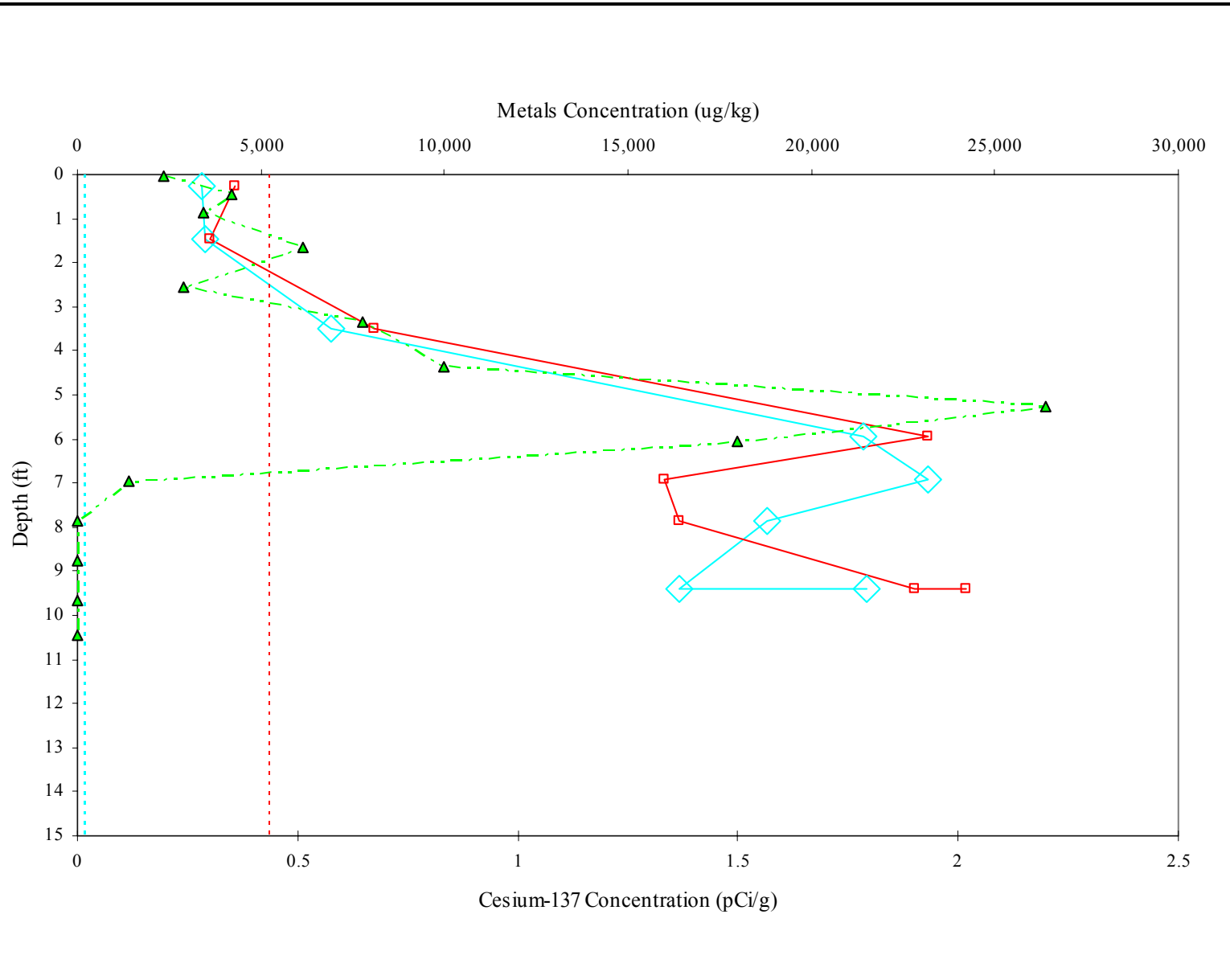http://www.state.nj.us/dep/
dsr/research/ambient-
levels-metal.pdf

Downcore Profile for Copper and Chromium
(River Mile 6.3)
Lower Passaic River Restoration Project

Figure 4-12I

February 2006
Draft

MALCOLM
PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Legend

— Copper Detect
— Chromium Detect
---- Copper Background
····· Chromium Background
-▲- Cesium-137

Location

June 1995, River Mile 6.4
TSI Location 298

Notes

Metals background concentrations were taken from Saunders, P. F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Copper and Chromium
(River Mile 6.4)
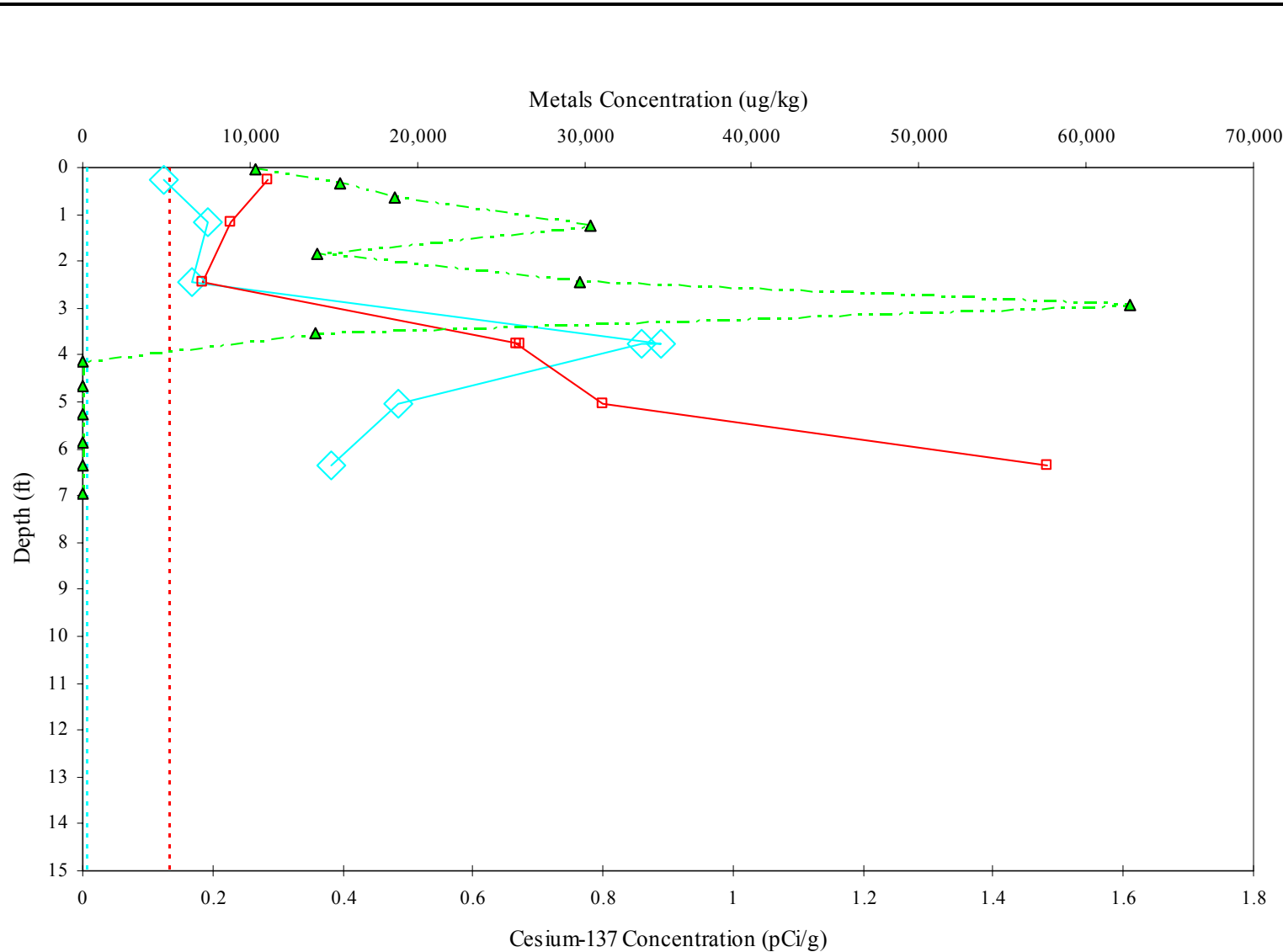Lower Passaic River Restoration Project

Figure 4-12m

February 2006
Draft

Downcore Profile for Copper and Chromium
(River Mile 6.5)
Lower Passaic River Restoration Project

Figure 4-12n

February 2006
Draft

Legend

□ Copper Detect
○ Chromium Detect
Copper Background
Chromium Background
▲ Cesium-137

Location

June 1995, River Mile 6.5
TSI Location 275

Notes

Metals background concentrations were taken from Saunders, P. F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Legend

- ◇— Cadmium Detect
- □— Arsenic Detect
- ⋯⋯ Cadmium Background
- ⋯⋯ Arsenic Background
- ▲·— Cesium-137

Location

April 1995, River Mile 1.5
TSI Location 209

Notes

Metals background concentrations were taken from Sanders, P.F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Cadmium and Arsenic
(River Mile 1.5)
Lower Passaic River Restoration Project

Figure 4-13a

February 2006
Draft

Downcore Profile for Cadmium and Arsenic
(River Mile 2.7)
Lower Passaic River Restoration Project

Figure 4-13b

February 2006
Draft

Legend

— ◇ — Cadmium Detect

— □ — Arsenic Detect

········· Cadmium Background

········· Arsenic Background

— ▲ — Cesium-137

Location

April 1995, River Mile 2.7
TSI Location 222

Notes

Metals background concentrations were taken from
Sanders, P.F., May 2003. "Ambient Levels of
Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/
dsr/research/ambient-levels-metal.pdf

Metals Concentration (ug/kg)

Legend

- Cadmium Detect
- Arsenic Detect
- Cadmium Background
- Arsenic Background
- Cesium-137

Location

May 1995, River Mile 3.1
TSI Location 228

Notes

Metals background concentrations were taken from Sanders, P.F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Depth (ft)

Cesium-137 Concentration (pCi/g)

Downcore Profile for Cadmium and Arsenic
(River Mile 3.1)
Lower Passaic River Restoration Project

Figure 4-13c

February 2006
Draft

MALCOLM PIRNIE

Legend

- Cadmium Detect
- Arsenic Detect
- Cadmium Background
- Arsenic Background
- Cesium-137

Location

May 1995, River Mile 3.1
TSI Location 230

Notes

Metals background concentrations were taken from Sanders, P.F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Cadmium and Arsenic
(River Mile 3.1)

Lower Passaic River Restoration Project

Figure 4-13d

February 2006
Draft

MALCOLM PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Cadmium and Arsenic
(River Mile 3.3)
Lower Passaic River Restoration Project

Figure 4-13e

February 2006
Draft

MALCOLM PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Cadmium and Arsenic
(River Mile 3.3)

Lower Passaic River Restoration Project

Figure 4-13f

February 2006
Draft
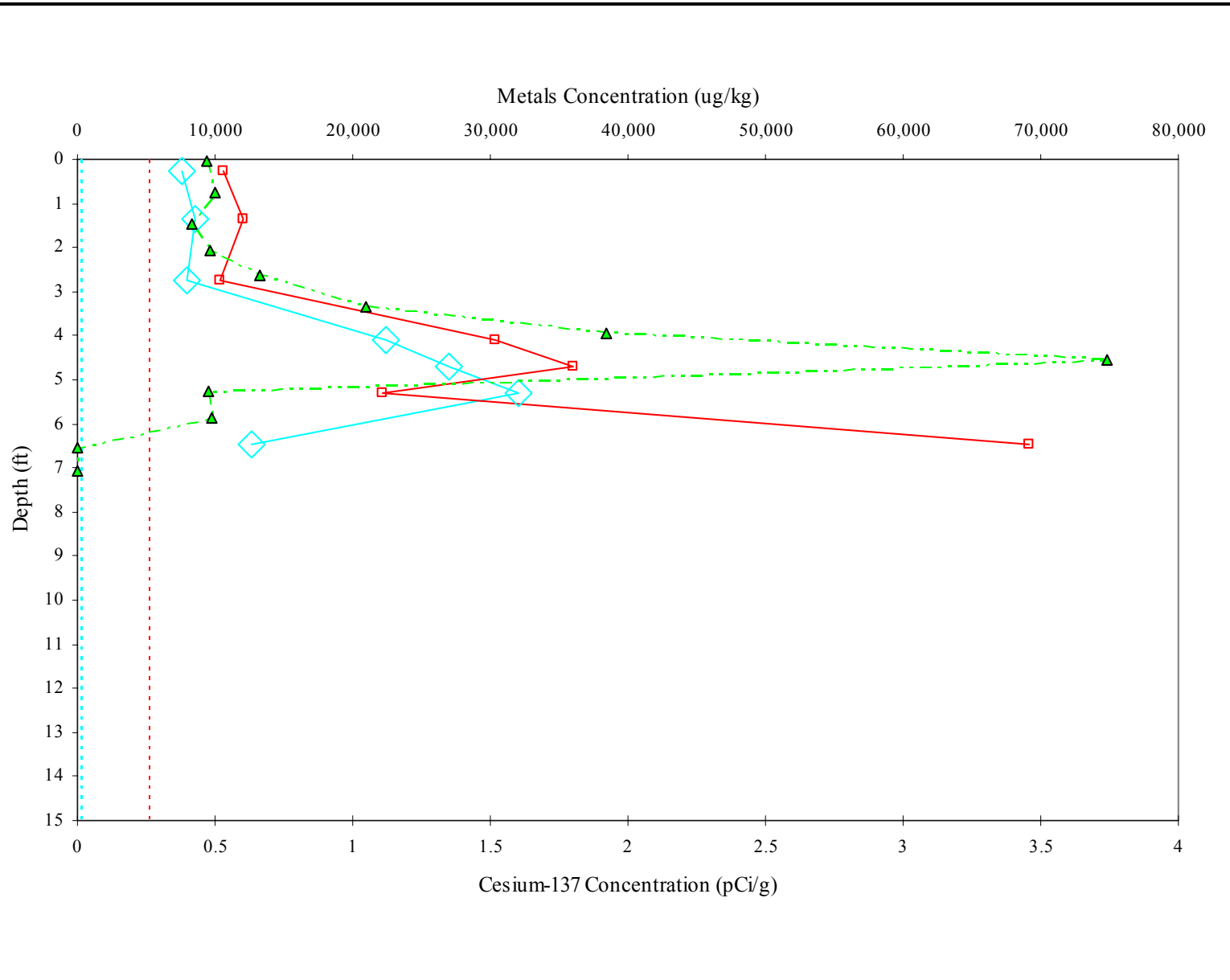
MALCOLM
PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Location

May 1995, River Mile 3.6
TSI Location 235

Notes

Metals background concentrations were taken from
Sanders, P.F., May 2003. "Ambient Levels of
Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/
dsr/research/ambient-levels-metal.pdf

Downcore Profile for Cadmium and Arsenic
(River Mile 3.6)
Lower Passaic River Restoration Project

Figure 4-13g

February 2006
Draft
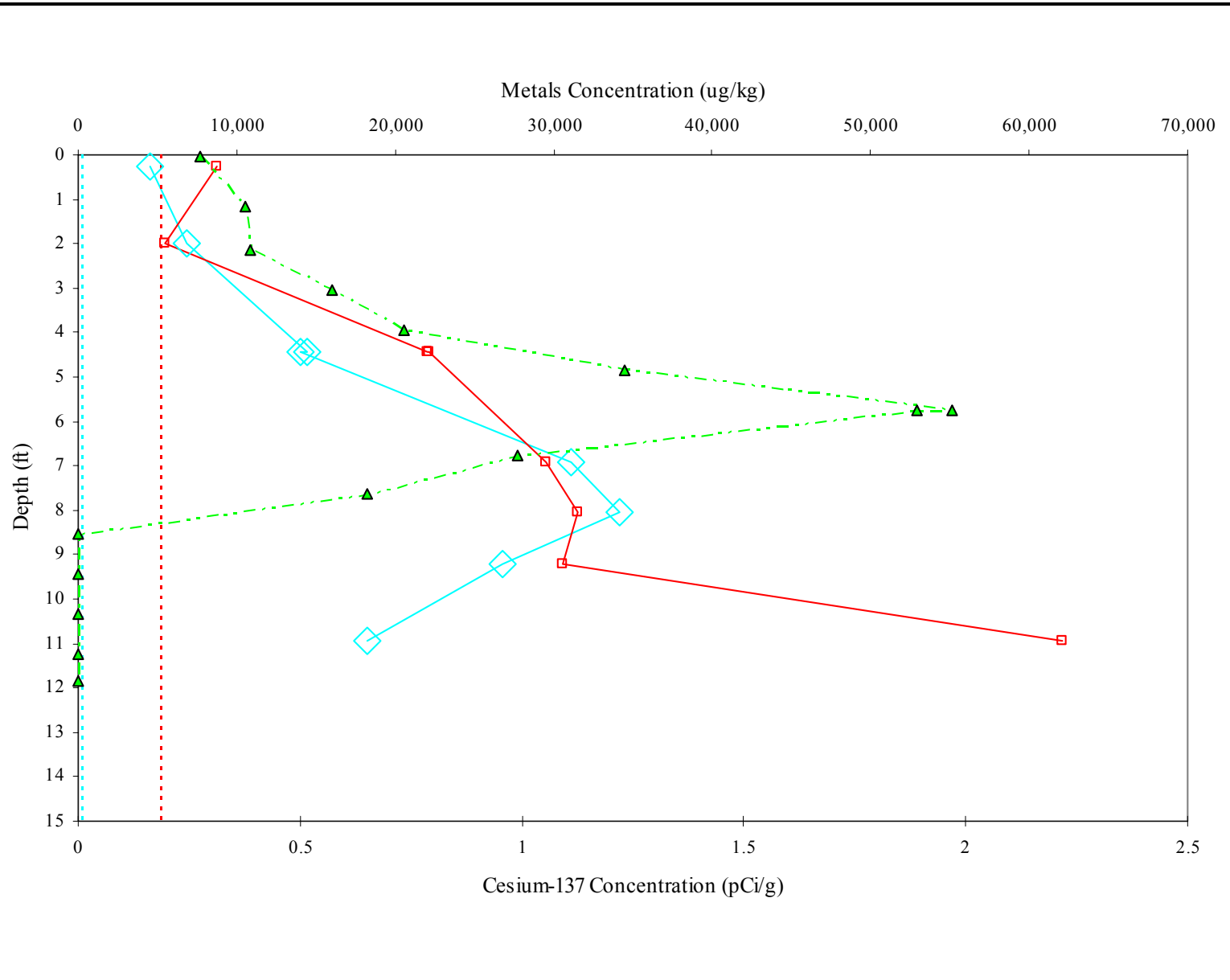
MALCOLM
PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Cadmium and Arsenic
(River Mile 4.0)

Lower Passaic River Restoration Project

Figure 4-13h

February 2006
Draft

MALCOLM PIRNIE

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Legend

- Cadmium Detect
- Cadmium Nondetect
- Arsenic Detect
- Cadmium Background
- Arsenic Background
- Cesium-137

Location

May 1995, River Mile 4.5
TSI Location 248

Notes

Metals background concentrations were taken from Sanders, P.F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Downcore Profile for Cadmium and Arsenic
(River Mile 4.5)
Lower Passaic River Restoration Project

Figure 4-13i

February 2006
Draft

MALCOLM PIRNIE

Metals Concentration (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)
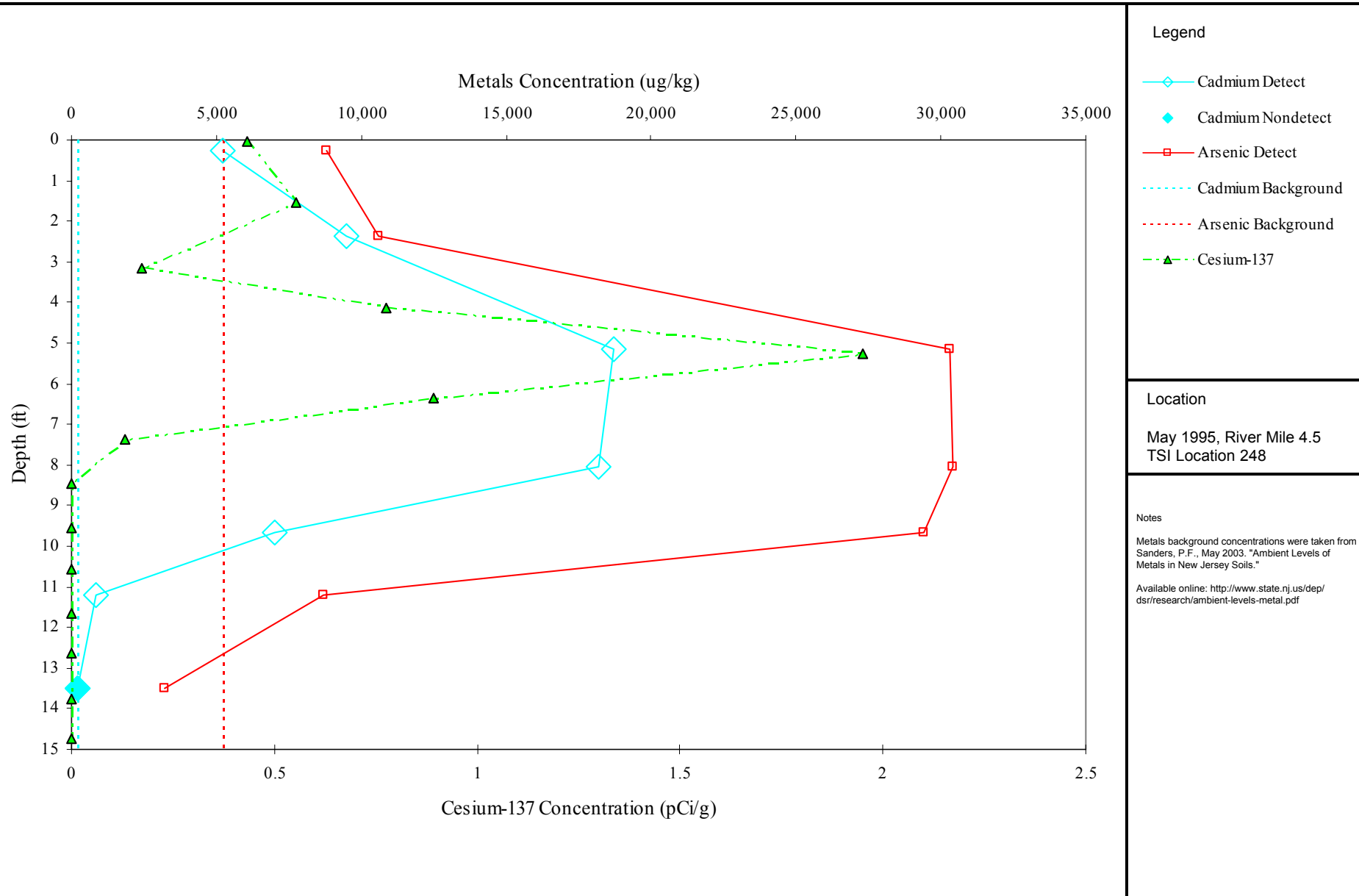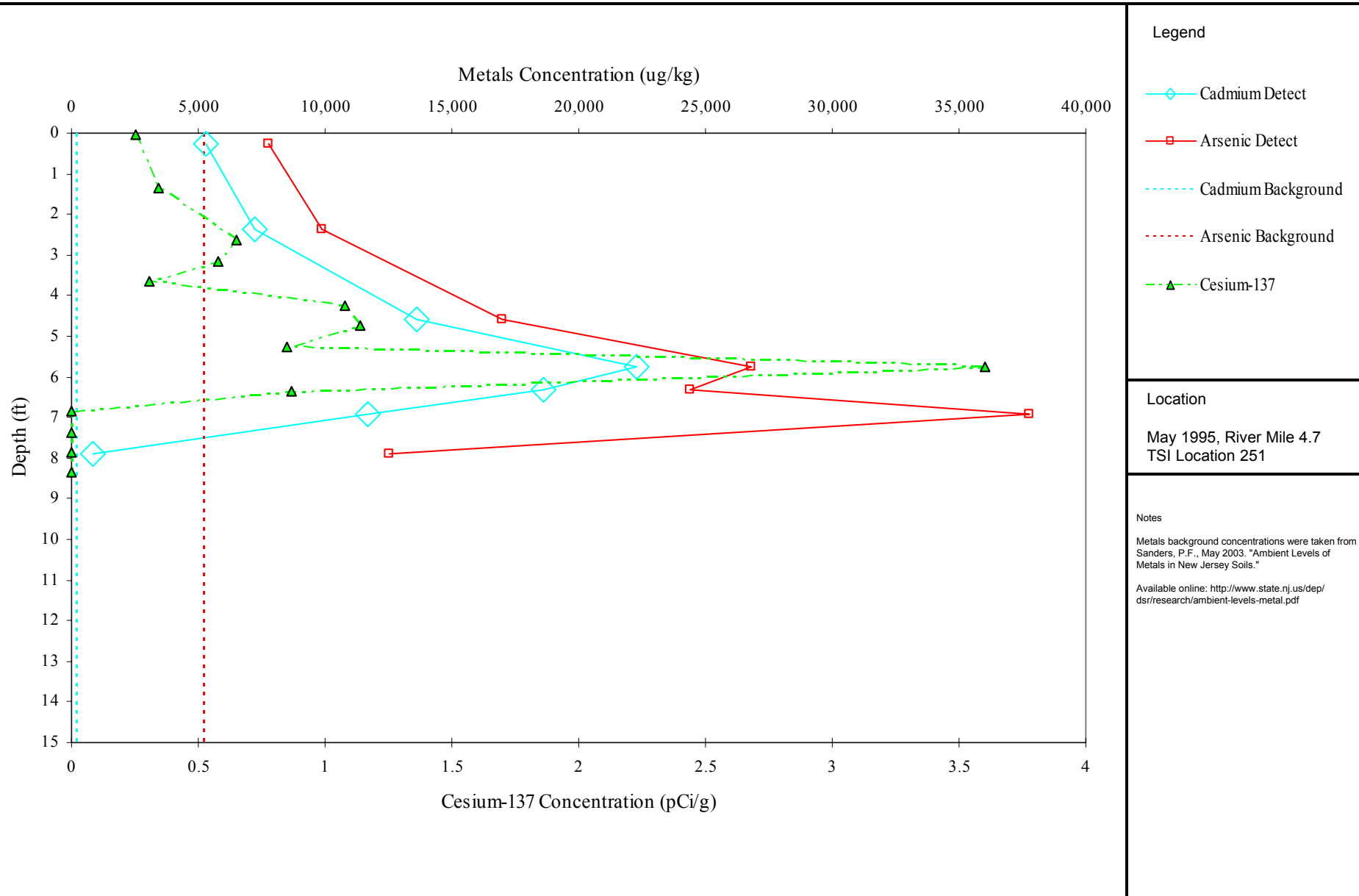
Downcore Profile for Cadmium and Arsenic
(River Mile 4.7)
Lower Passaic River Restoration Project

Figure 4-13j

February 2006
Draft

MALCOLM
PIRNIE

Metals Concentration (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)
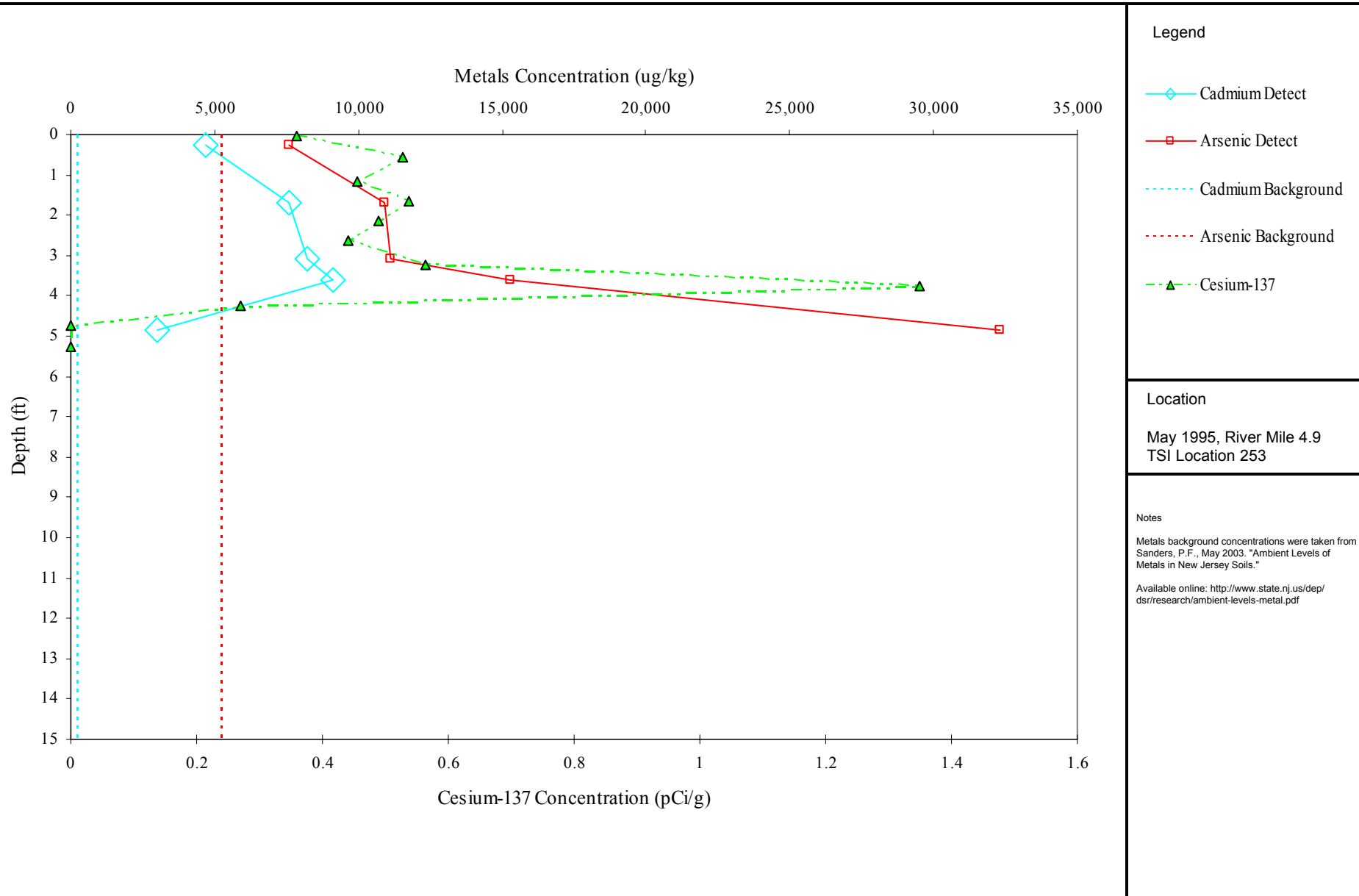
Downcore Profile for Cadmium and Arsenic
(River Mile 4.9)
Lower Passaic River Restoration Project

Figure 4-13k

February 2006
Draft

MALCOLM PIRNIE

Metals Concentration (ug/kg)

Depth (ft)

Cesium-137 Concentration (pCi/g)

Downcore Profile for Cadmium and Arsenic
(River Mile 6.3)

Lower Passaic River Restoration Project

Figure 4-13I

February 2006
Draft

MALCOLM
PIRNIE

Legend

- Cadmium Detect
- Arsenic Detect
- Cadmium Background
- Arsenic Background
- Cesium-137

Location

June 1995, River Mile 6.4
TSI Location 296

Notes

Metals background concentrations were taken from Sanders, P.F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf
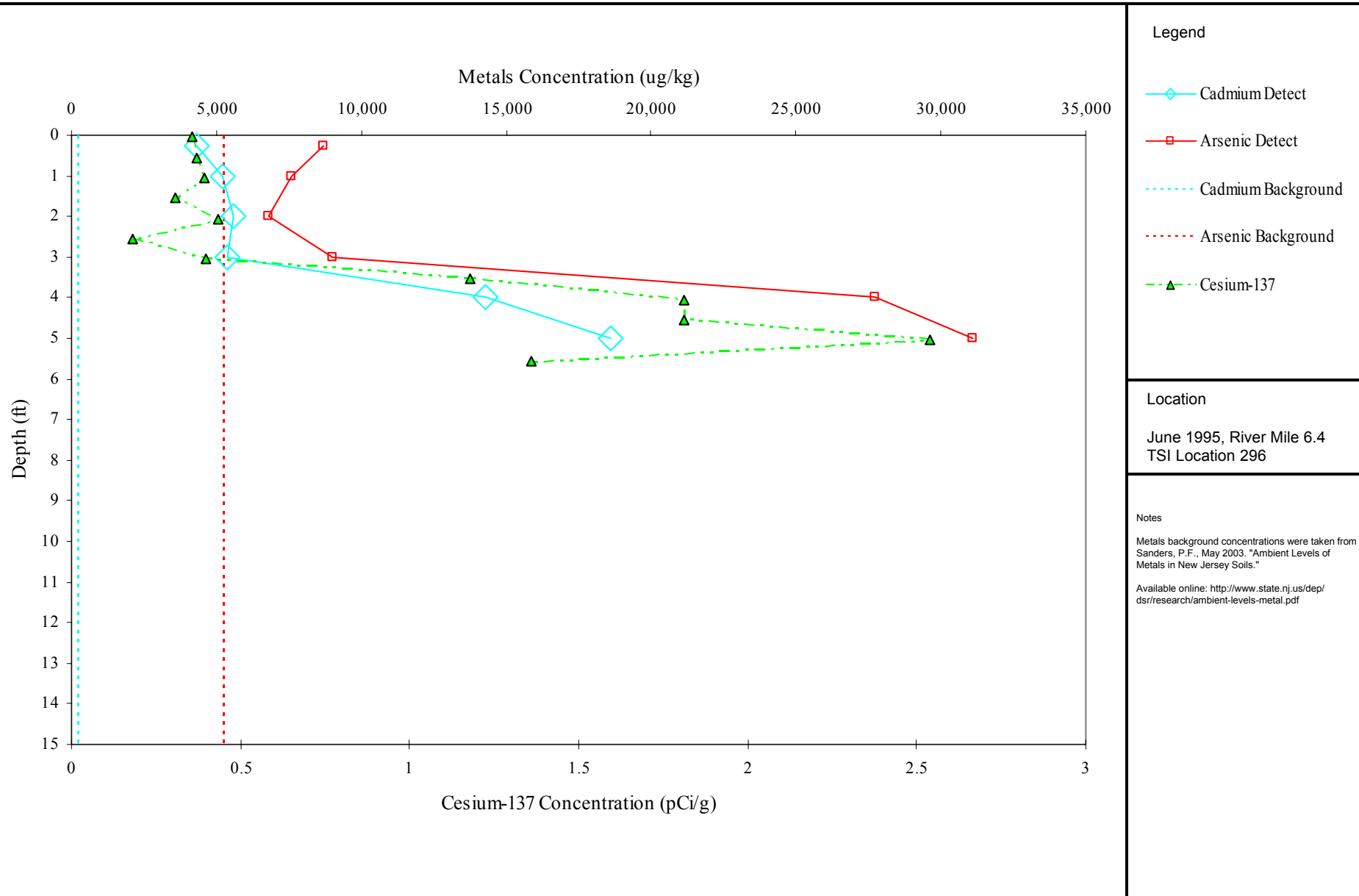
Downcore Profile for Cadmium and Arsenic
(River Mile 6.4)

Lower Passaic River Restoration Project

Figure 4-13m

February 2006
Draft

Legend

- Cadmium Detect
- Arsenic Detect
- Cadmium Background
- Arsenic Background
- Cesium-137

Location

June 1995, River Mile 6.5
TSI Location 275

Notes

Metals background concentrations were taken from Sanders, P.F., May 2003. "Ambient Levels of Metals in New Jersey Soils."

Available online: http://www.state.nj.us/dep/dsr/research/ambient-levels-metal.pdf

Metals Concentration (ug/kg)

Cesium-137 Concentration (pCi/g)

Depth (ft)

Downcore Profile for Cadmium and Arsenic
(River Mile 6.5)
Lower Passaic River Restoration Project

Figure 4-13n

February 2006
Draft
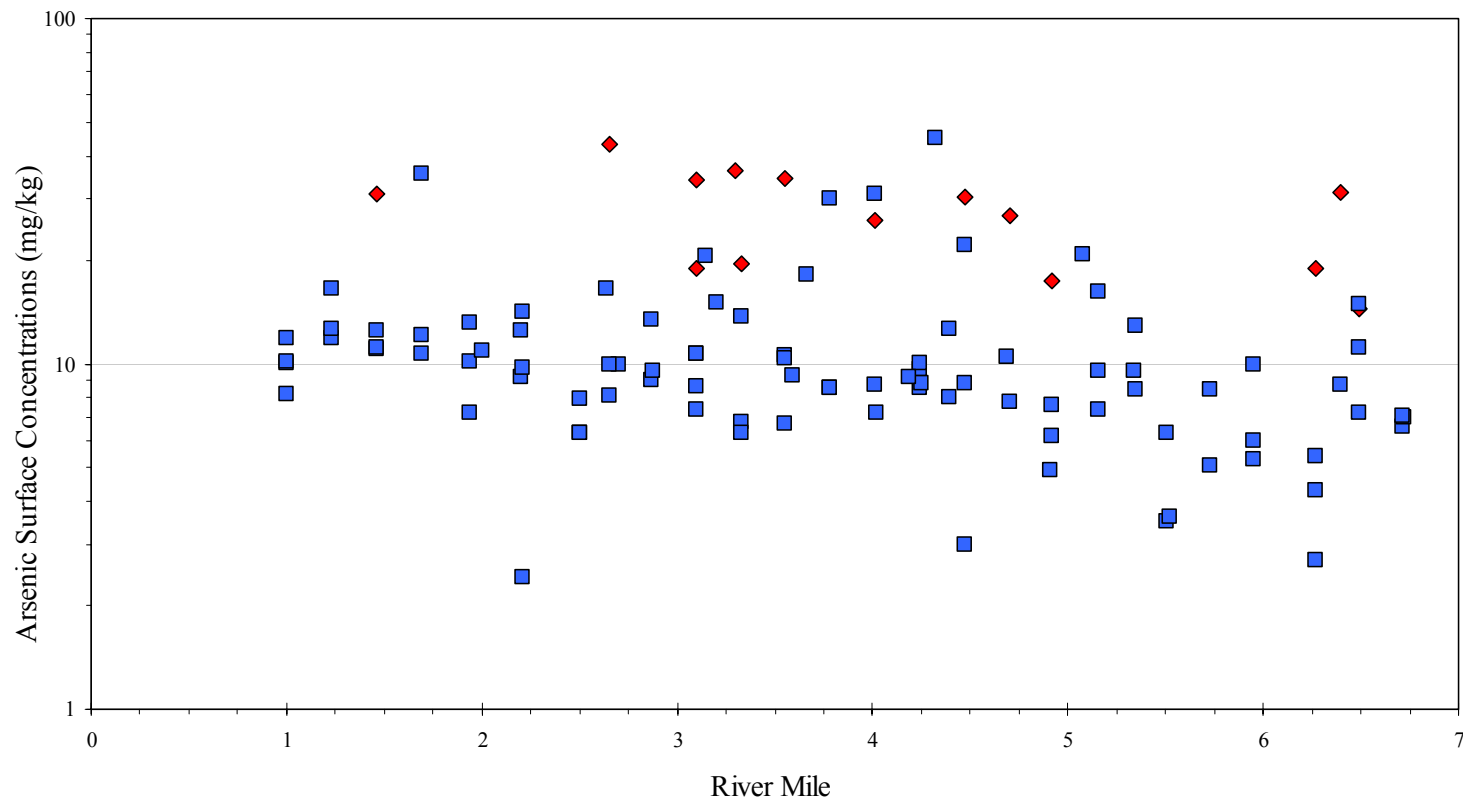
MALCOLM PIRNIE

Comparison of Concentrations in 1963 and 1995, Arsenic

Lower Passaic River Restoration Project

Figure 4-14a

February 2006
Draft
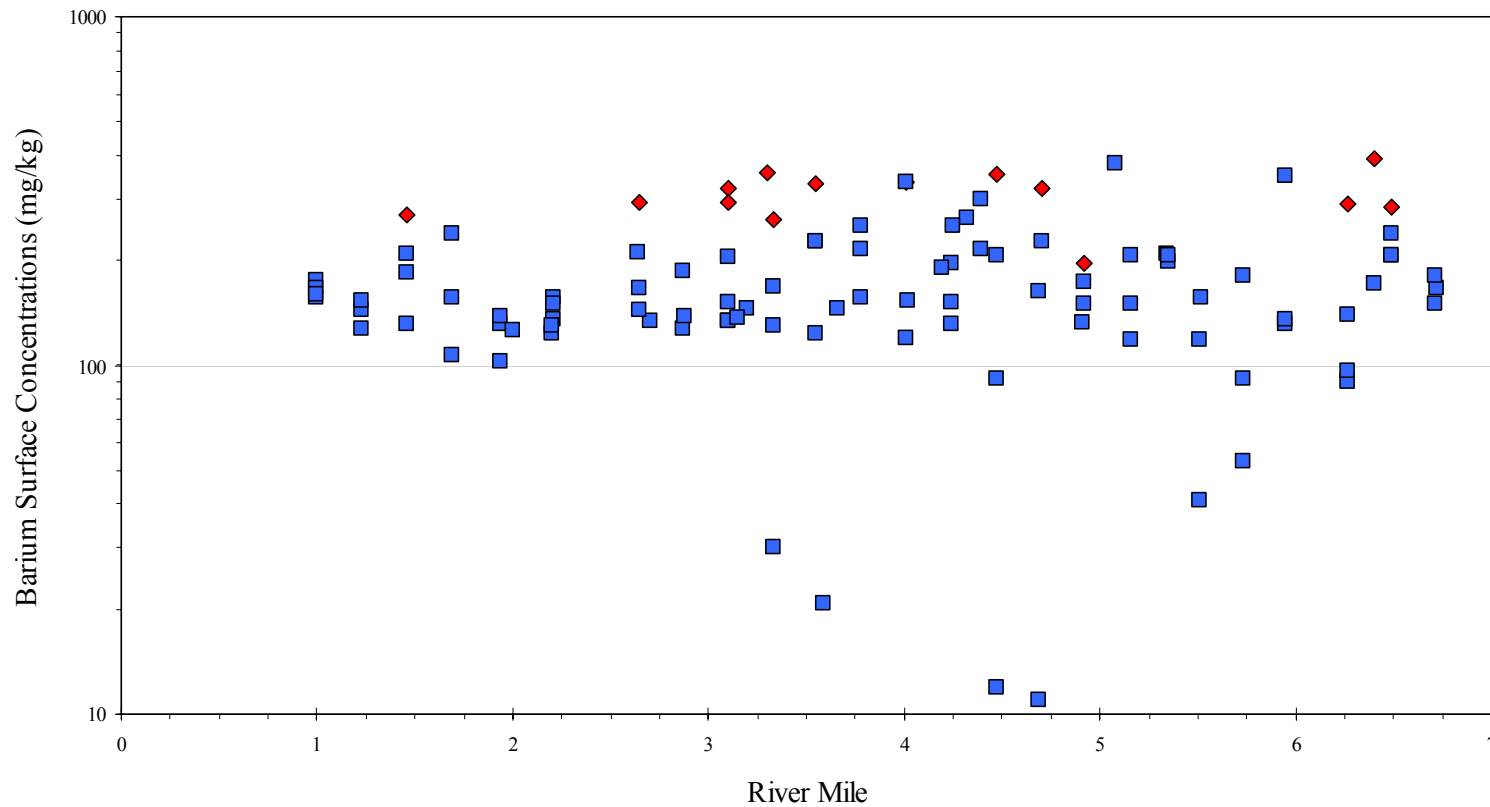
Comparison of Concentrations in 1963 and 1995, Barium

Lower Passaic River Restoration Project
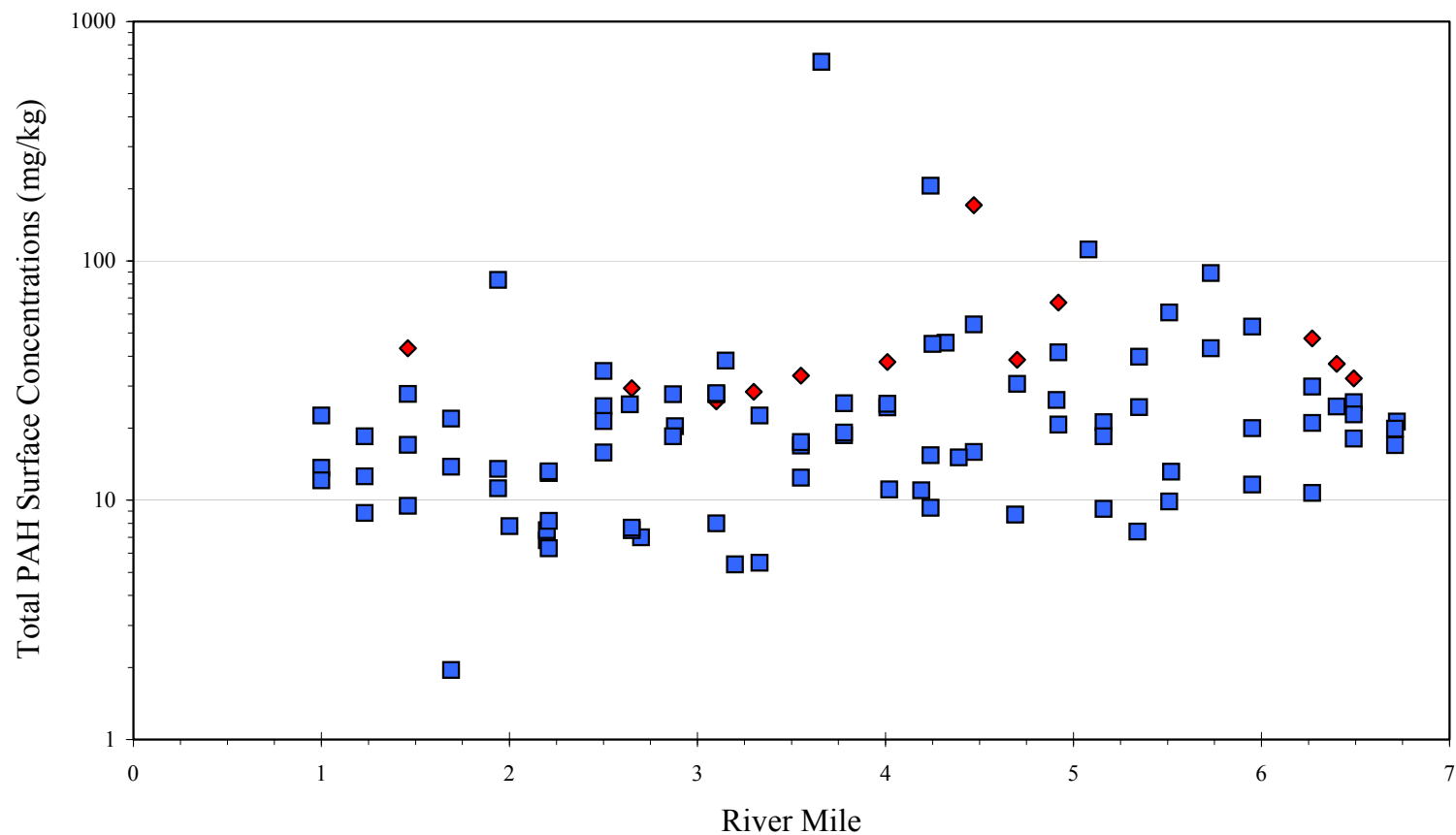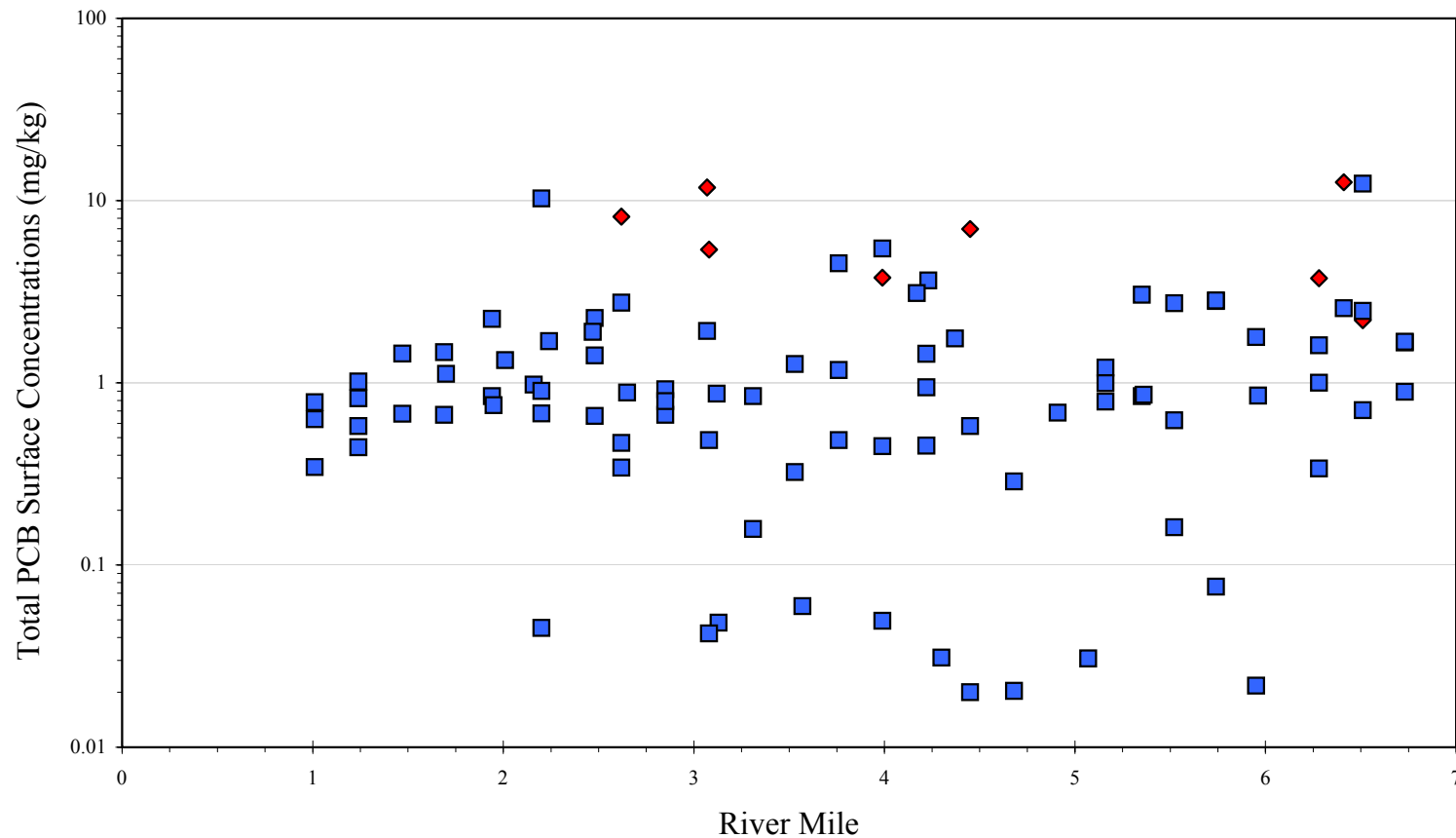
Figure 4-14b

February 2006
Draft
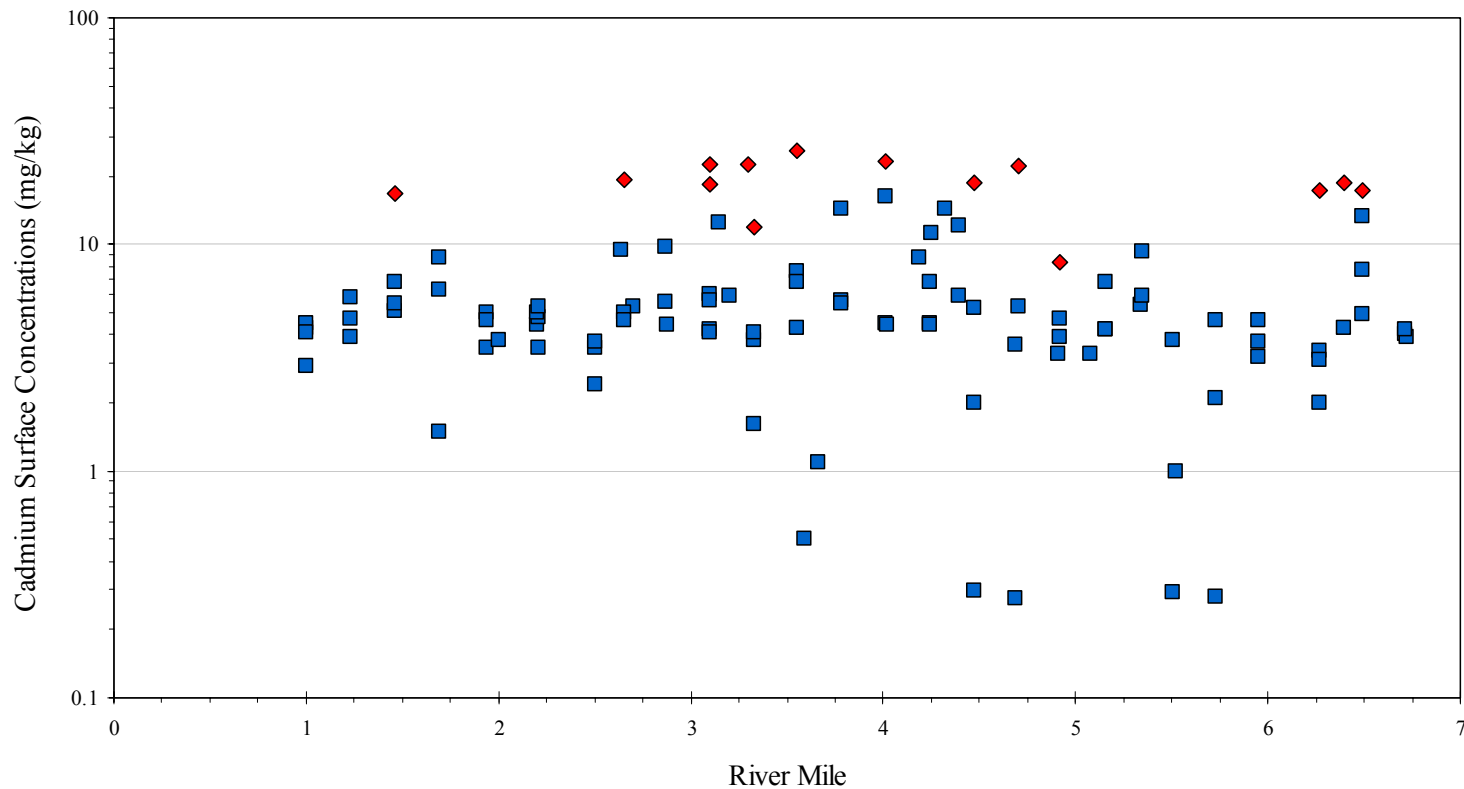
Figure 4-14c

Comparison of Concentrations in 1963 and 1995, Cadmium

Lower Passaic River Restoration Project

February 2006
Draft
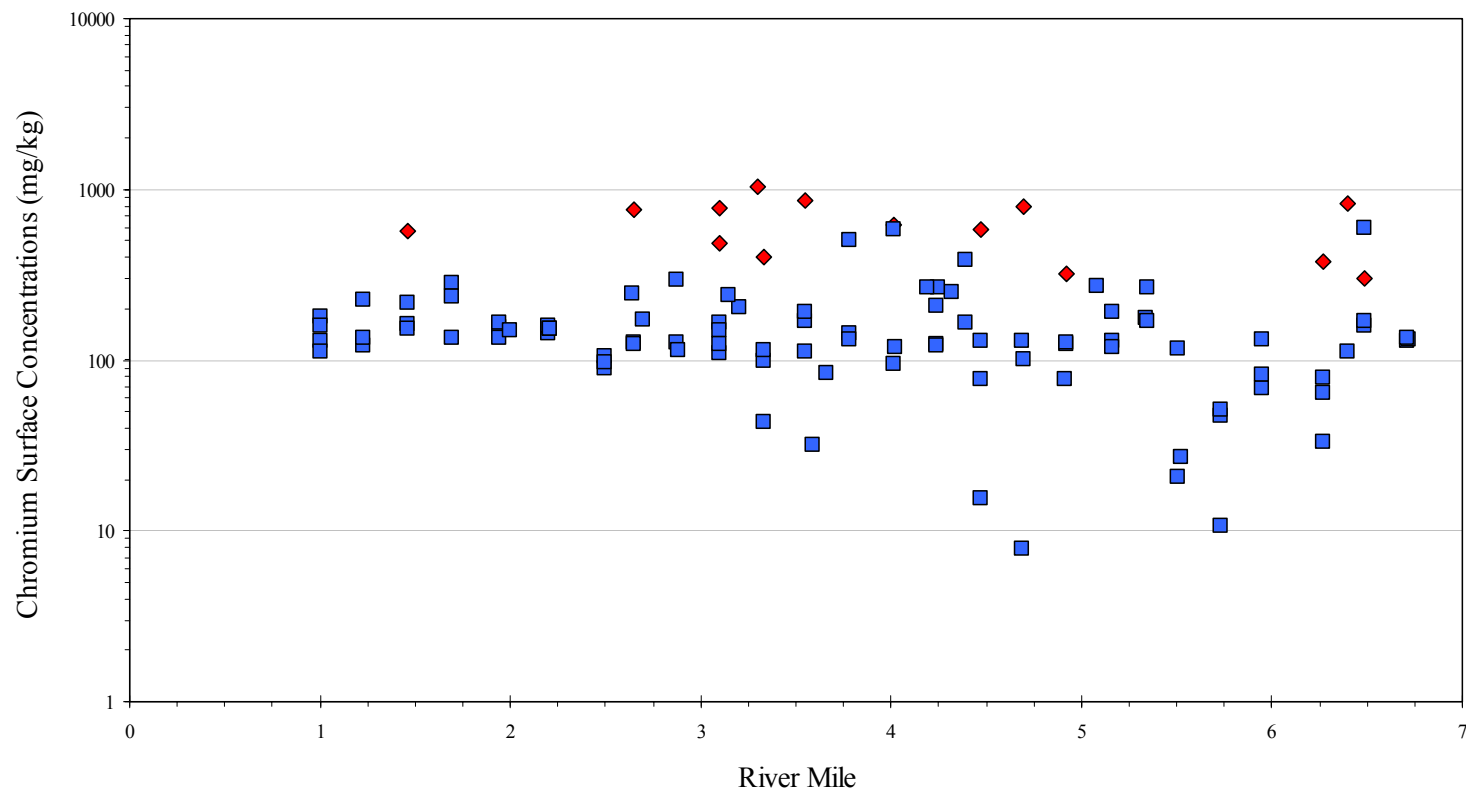
Comparison of Concentrations in 1963 and 1995, Chromium

Lower Passaic River Restoration Project

Figure 4-14d

February 2006
Draft

Legend

◆ Chromium Surface Concentrations (1963)
◼ Chromium Surface Concentrations (1995)

Location

Notes

1995 Tierra Solutions Inc Dataset

"Surface Concentration 1995" = concentrations at 0 to 0.5 foot

"Concentrations at 1963" = interpolated concentration at depth of the corresponding cesium-137 peak

Non-detect (lab qualifier containing a U) plotted as half the reported detection limit
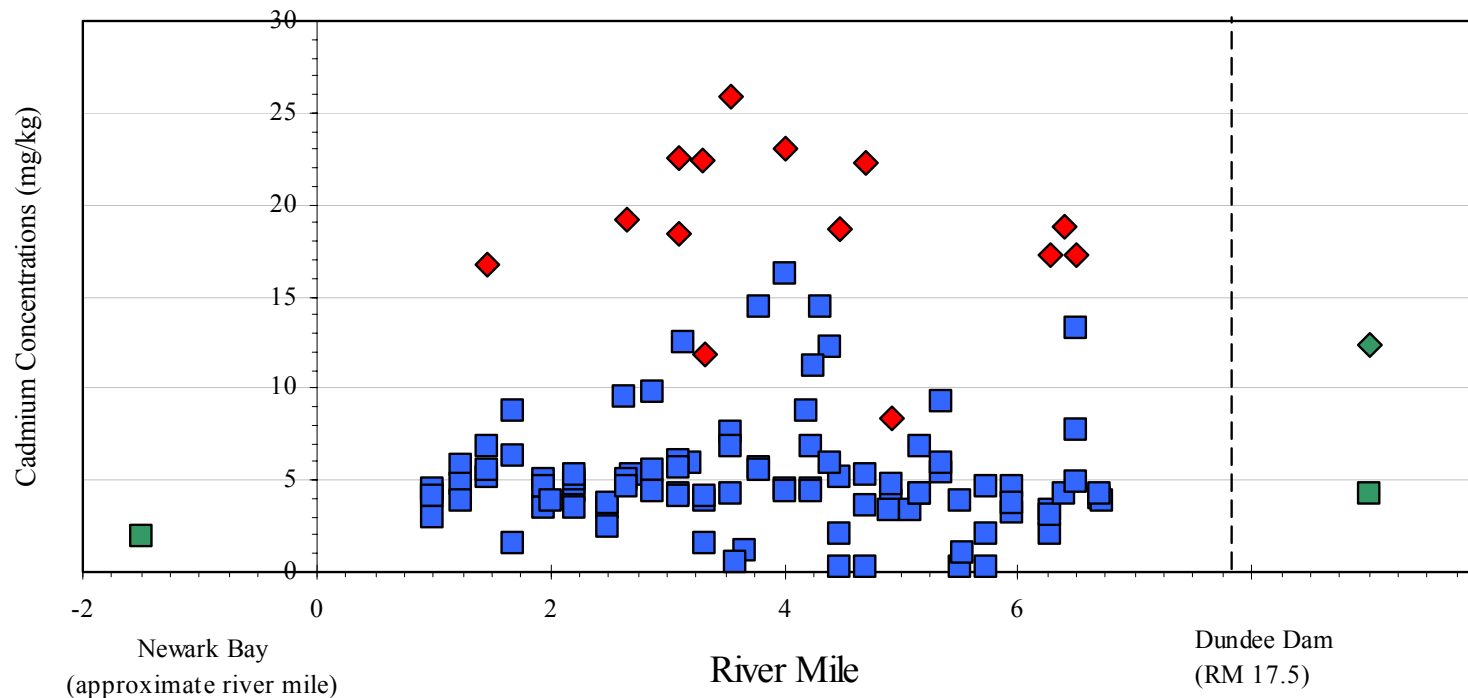
US Army Corps
of Engineers®

Legend

◆ Copper Surface Concentrations (1963)

■ Copper Surface Concentrations (1995)

Location

Notes

1995 Tierra Solutions Inc Dataset

"Surface Concentration 1995" = concentrations at 0 to 0.5 foot

"Concentrations at 1963" = interpolated concentration at depth of the corresponding cesium-137 peak

Non-detect (lab qualifier containing a U) plotted as half the reported detection limit

Comparison of Concentrations in 1963 and 1995, Copper

Lower Passaic River Restoration Project

Figure 4-14e

February 2006
Draft

MALCOLM PIRNIE
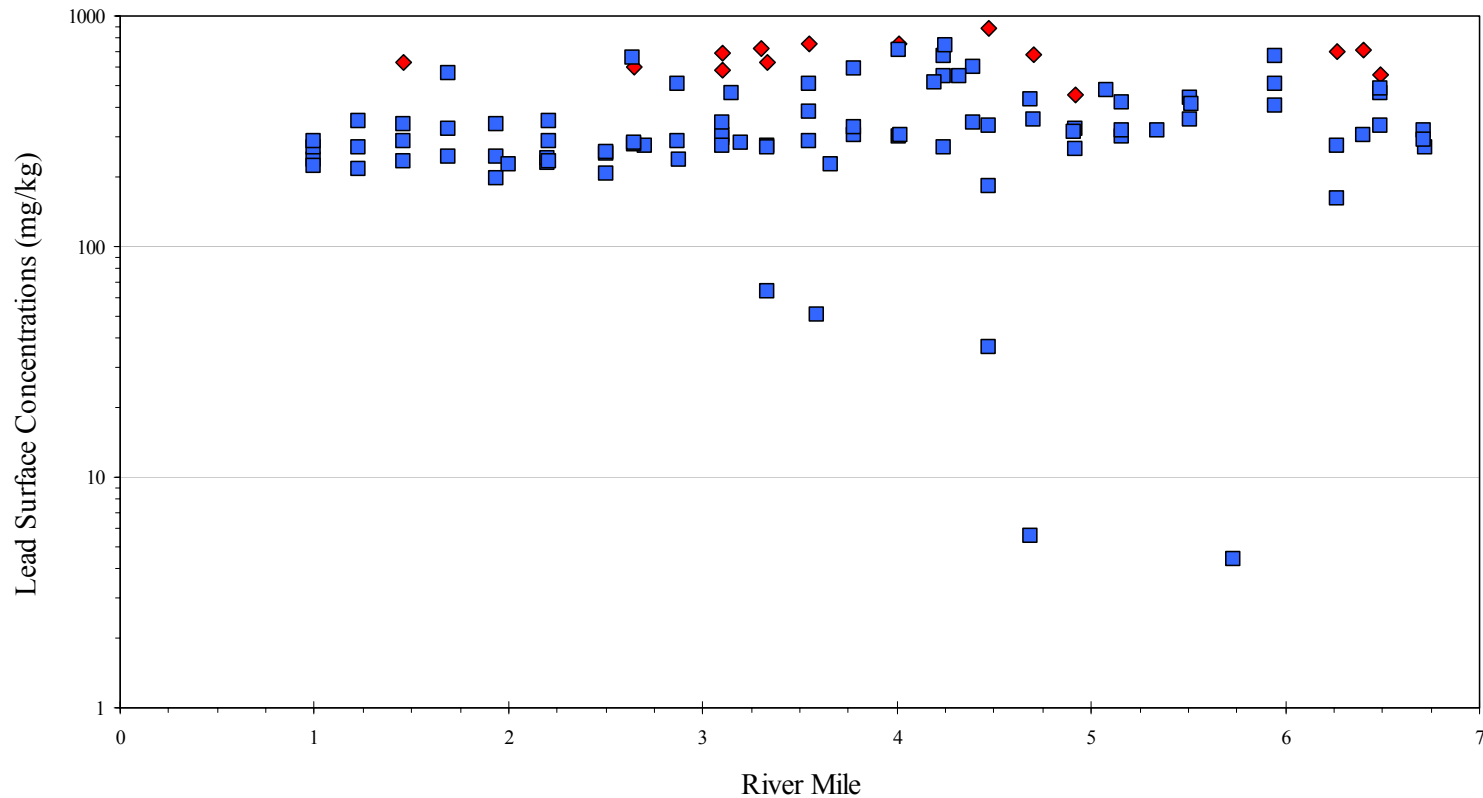
Legend

◆ Lead Surface Concentrations (1963)
■ Lead Surface Concentrations (1995)

Location

Notes

1995 Tierra Solutions Inc Dataset

"Surface Concentration 1995" = concentrations at 0 to 0.5 foot

"Concentrations at 1963" = interpolated concentration at depth of the corresponding cesium-137 peak

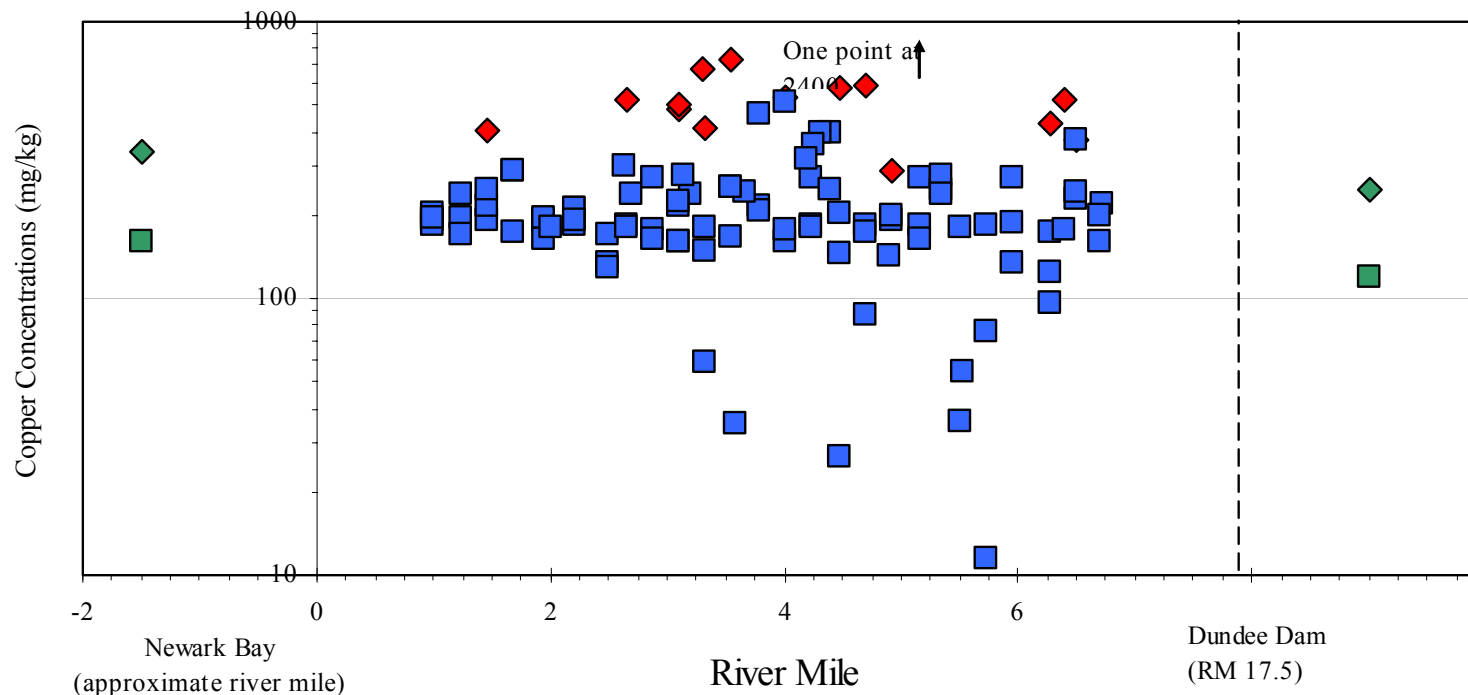Non-detect (lab qualifier containing a U) plotted as half the reported detection limit

Comparison of Concentrations in 1963 and 1995, Lead

Lower Passaic River Restoration Project

Figure 4-14f

February 2006
Draft

Legend

◆ Mercury Surface Concentrations (1963)
■ Mercury Surface Concentrations (1995)

Location

Notes

1995 Tierra Solutions Inc Dataset

"Surface Concentration 1995" = concentrations at 0 to 0.5 foot

"Concentrations at 1963" = interpolated concentration at depth of the corresponding cesium-137 peak

Non-detect (lab qualifier containing a U) plotted as half the reported detection limit
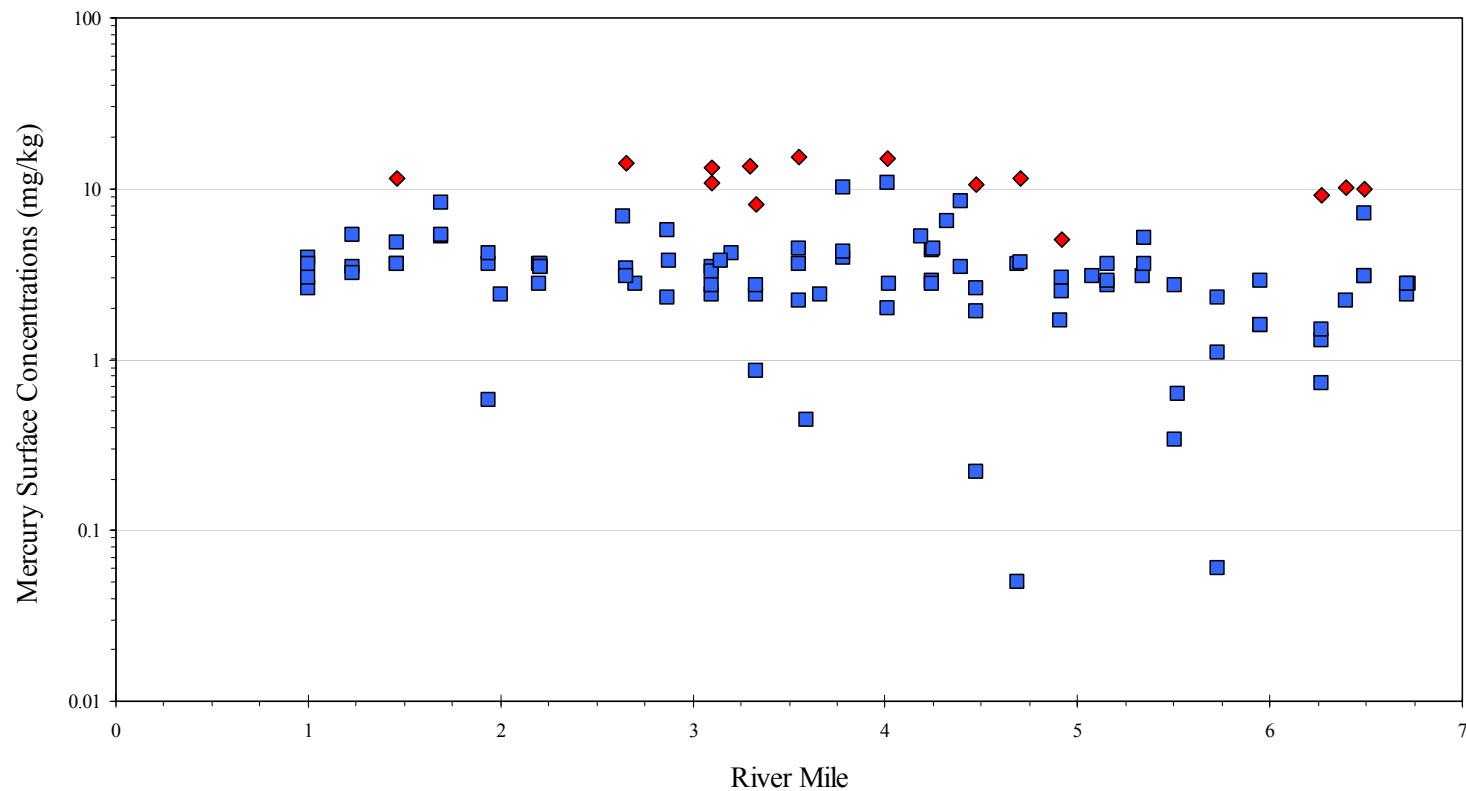
Comparison of Concentrations in 1963 and 1995, Mercury

Lower Passaic River Restoration Project

Figure 4-14g

February 2006
Draft
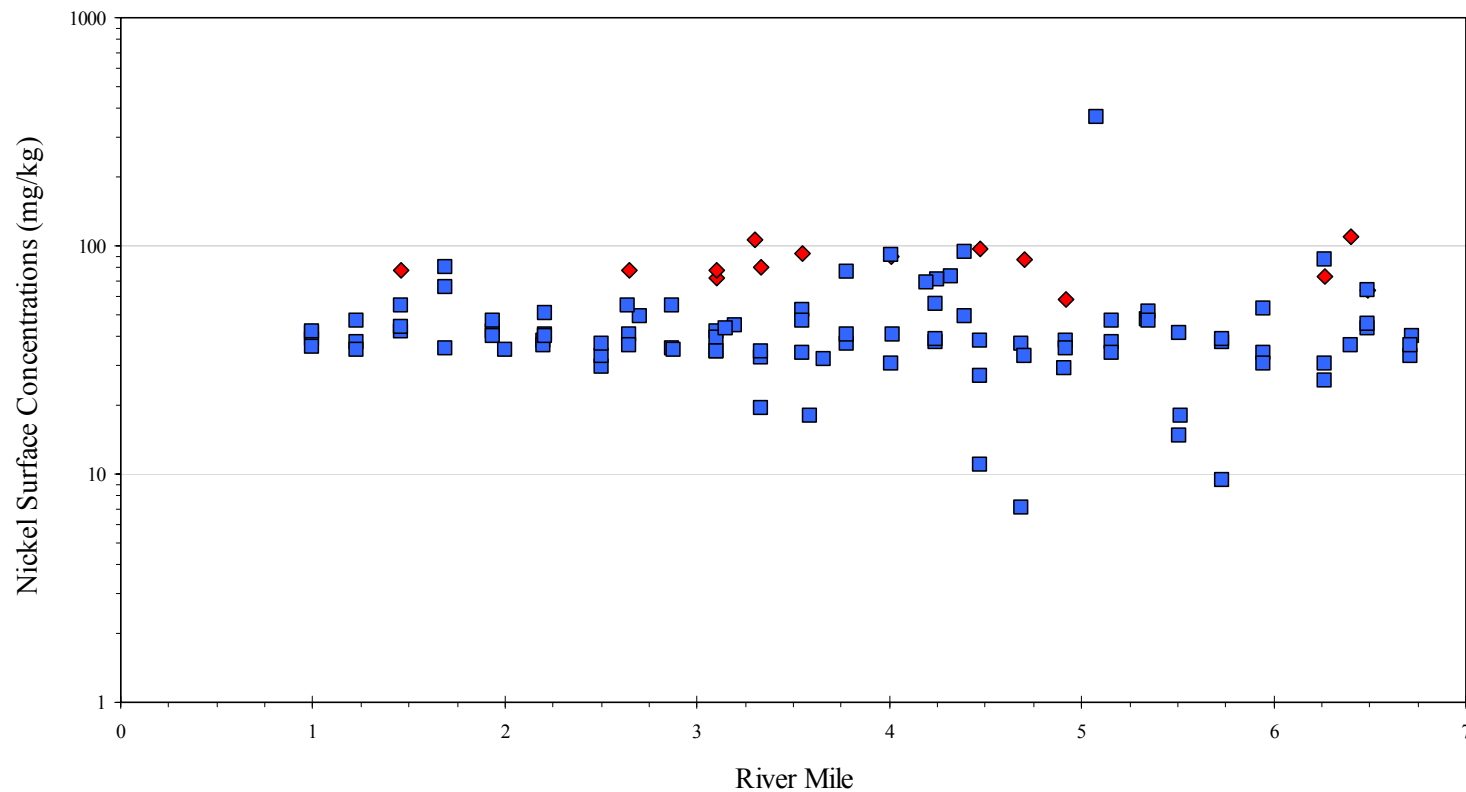
US Army Corps of Engineers

MALCOLM PIRNIE

Comparison of Concentrations in 1963 and 1995, Nickel

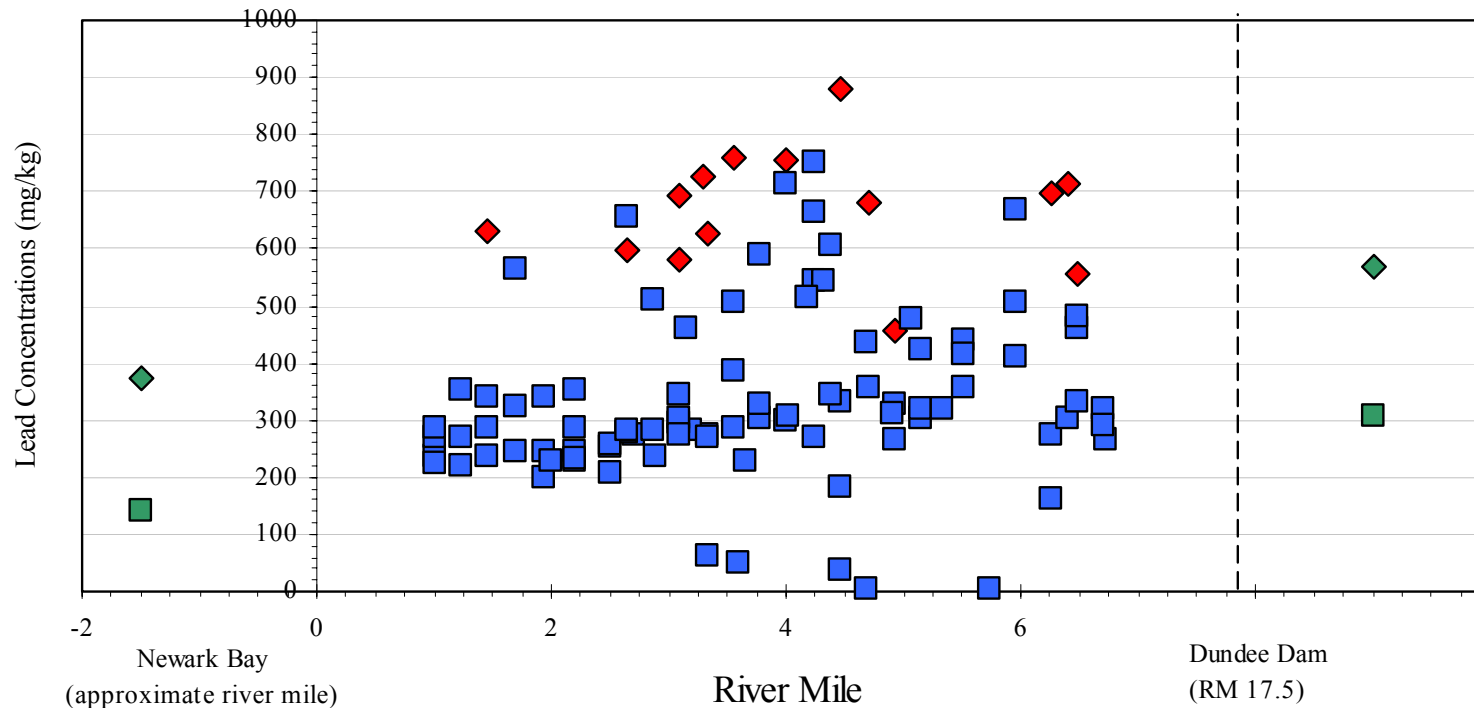*Lower Passaic River Restoration Project*

Figure 4-14h

February 2006
Draft
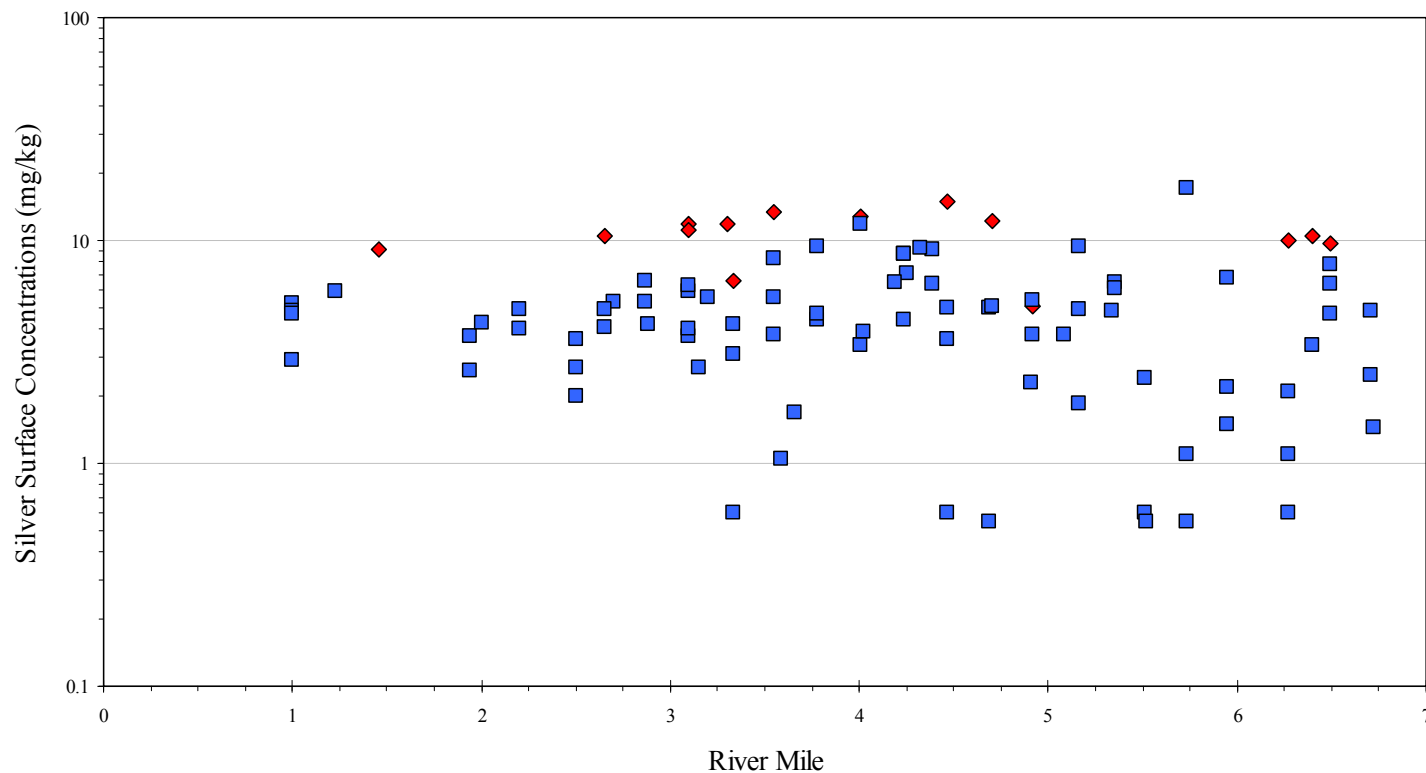
Comparison of Concentrations in 1963 and 1995, Silver

Lower Passaic River Restoration Project

Figure 4-14i

February 2006
Draft

MALCOLM PIRNIE

Legend

- ◆ TCDD Surface Concentrations (1963)
- ■ TCDD Surface Concentrations (1995)

Location

Notes

1995 Tierra Solutions Inc Dataset

"Surface Concentration 1995" = concentrations at 0 to 0.5 foot

"Concentrations at 1963" = interpolated concentration at depth of the corresponding cesium-137 peak

Non-detect (lab qualifier containing a U) plotted as half the reported detection limit
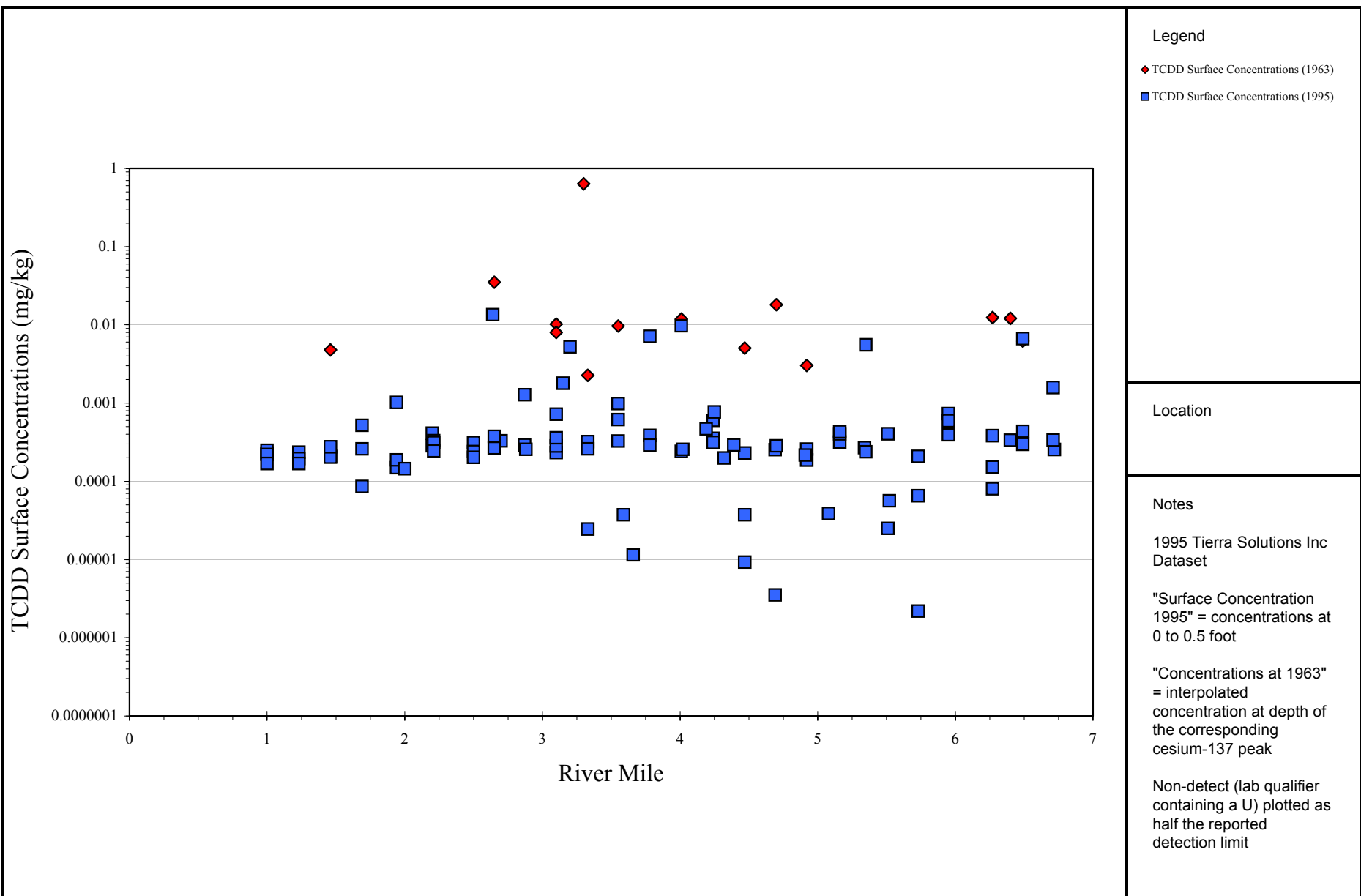
Comparison of Concentrations in 1963 and 1995, TCDD

Lower Passaic River Restoration Project

Figure 4-14j

February 2006
Draft

MALCOLM PIRNIE
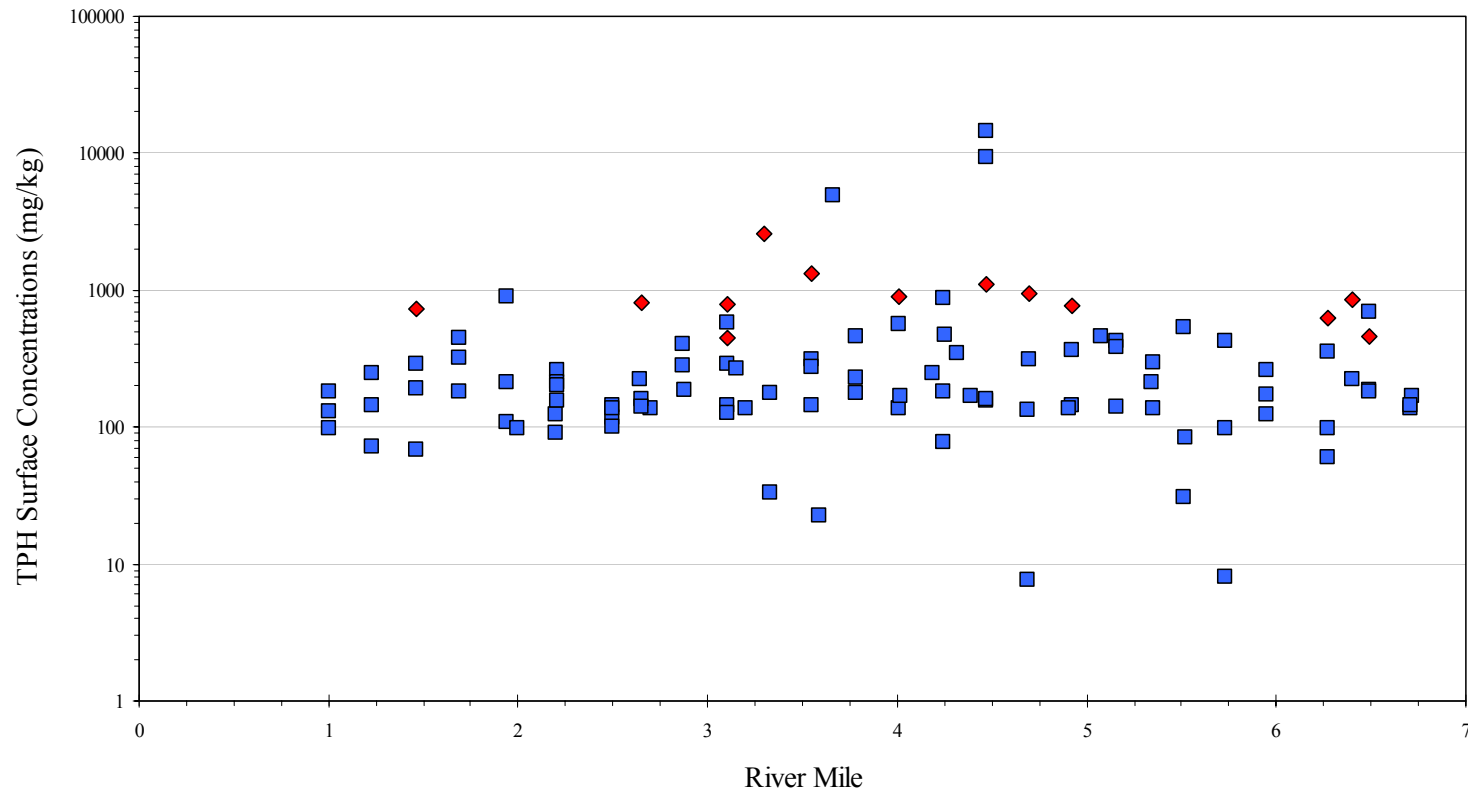
Comparison of Concentrations in 1963 and 1995, TPH

Lower Passaic River Restoration Project

Figure 4-14k

February 2006
Draft

Total PAH Surface Concentrations (mg/kg)

River Mile

Comparison of Concentrations in 1963 and 1995, Total PAH

Lower Passaic River Restoration Project

Figure 4-14l

February 2006
Draft

MALCOLM PIRNIE

Legend

◆ TPCB Surface Concentrations (1963)
■ TPCB Surface Concentrations (1995)

Location

Notes

1995 Tierra Solutions Inc Dataset

"Surface Concentration 1995" = concentrations at 0 to 0.5 foot

"Concentrations at 1963" = interpolated concentration at depth of the corresponding cesium-137 peak

Non-detect (lab qualifier containing a U) plotted as half the reported detection limit

Comparison of Concentrations in 1963 and 1995, Total PCB

Lower Passaic River Restoration Project

Figure 4-14m

February 2006
Draft

MALCOLM PIRNIE

Legend

◆ Tierra Solutions, Inc. (1963)

■ Tierra Solutions, Inc. (1995)

◆ Bopp et al., 2006 (1963)

■ Bopp et al., 2006 (1986-1995)

Location

Notes

Tierra Solutions Inc. Data Source:
PASSAIC 1995 RI Sampling Program (14 of the 95 locations for1963; all locations for 1995), Tierra Solutions, Inc. 1963 concentrations were calculated via interpolation at the depth corresponding to the cesium-137 peak

Surface concentrations are from a depth of 0 to <1 foot

Non-detect (lab qualifier containing a U) plotted as half the reported value

Bopp et al,. 2006 Data Source:
Contaminant Chronologies from Hudson River Sedimentary Records, Bopp et al.

Concentration at 1963 obtained from analysis of discrete core sections corresponding to the cesium-137 peak.

Surface concentrations are from a depth of 0 to <1 foot

Comparison of Concentrations ca 1963 and 1986-1995: Cadmium

Lower Passaic River Restoration Project

Figure 4-15a

February 2006
Draft

MALCOLM PIRNIE

Legend

◆ Tierra Solutions, Inc. (1963)

■ Tierra Solutions, Inc. (1995)

◆ Bopp et al., 2006 (1963)

■ Bopp et al., 2006 (1986-1995)

Location

Notes

Tierra Solutions Inc. Data Source:
PASSAIC 1995 RI Sampling Program (14 of the 95 locations for1963; all locations for 1995), Tierra Solutions, Inc. 1963 concentrations were calculated via interpolation at the depth corresponding to the cesium-137 peak

Surface concentrations are from a depth of 0 to <1 foot

Non-detect (lab qualifier containing a U) plotted as half the reported value

Bopp et al,. 2006 Data Source:
Contaminant Chronologies from Hudson River Sedimentary Records, Bopp et al.

Concentration at 1963 obtained from analysis of discrete core sections corresponding to the cesium-137 peak.

Surface concentrations are from a depth of 0 to <1 foot

Comparison of Concentrations ca 1963 and 1986-1995: Copper

Lower Passaic River Restoration Project

Figure 4-15b

February 2006
Draft

MALCOLM PIRNIE

Legend

◆ Tierra Solutions, Inc. (1963)

■ Tierra Solutions, Inc. (1995)

◆ Bopp et al., 2006 (1963)

■ Bopp et al., 2006 (1986-1995)

Location

Notes

Tierra Solutions Inc. Data Source:
PASSAIC 1995 RI Sampling Program (14 of the 95 locations for1963; all locations for 1995), Tierra Solutions, Inc. 1963 concentrations were calculated via interpolation at the depth corresponding to the cesium-137 peak

Surface concentrations are from a depth of 0 to <1 foot

Non-detect (lab qualifier containing a U) plotted as half the reported value

Bopp et al,. 2006 Data Source:
Contaminant Chronologies from Hudson River Sedimentary Records, Bopp et al.

Concentration at 1963 obtained from analysis of discrete core sections corresponding to the cesium-137 peak.

Surface concentrations are from a depth of 0 to <1 foot

Comparison of Concentrations ca 1963 and 1986-1995: Lead

Lower Passaic River Restoration Project

Figure 4-15c

February 2006
Draft

MALCOLM PIRNIE

Mercury Concentrations (mg/kg)

16
14
12
10
8
6
4
2
0

River Mile

-2   0   2   4   6

Newark Bay
(approximate river mile)

Dundee Dam
(RM 17.5)

Comparison of Concentrations ca 1963 and 1986-1995:
Mercury

Lower Passaic River Restoration Project

Figure 4-15d

February 2006
Draft

MALCOLM PIRNIE

Comparison of 2,3,7,8-TCDD Concentrations in 1963, 1985, 1986, and 1995

Lower Passaic River Restoration Project
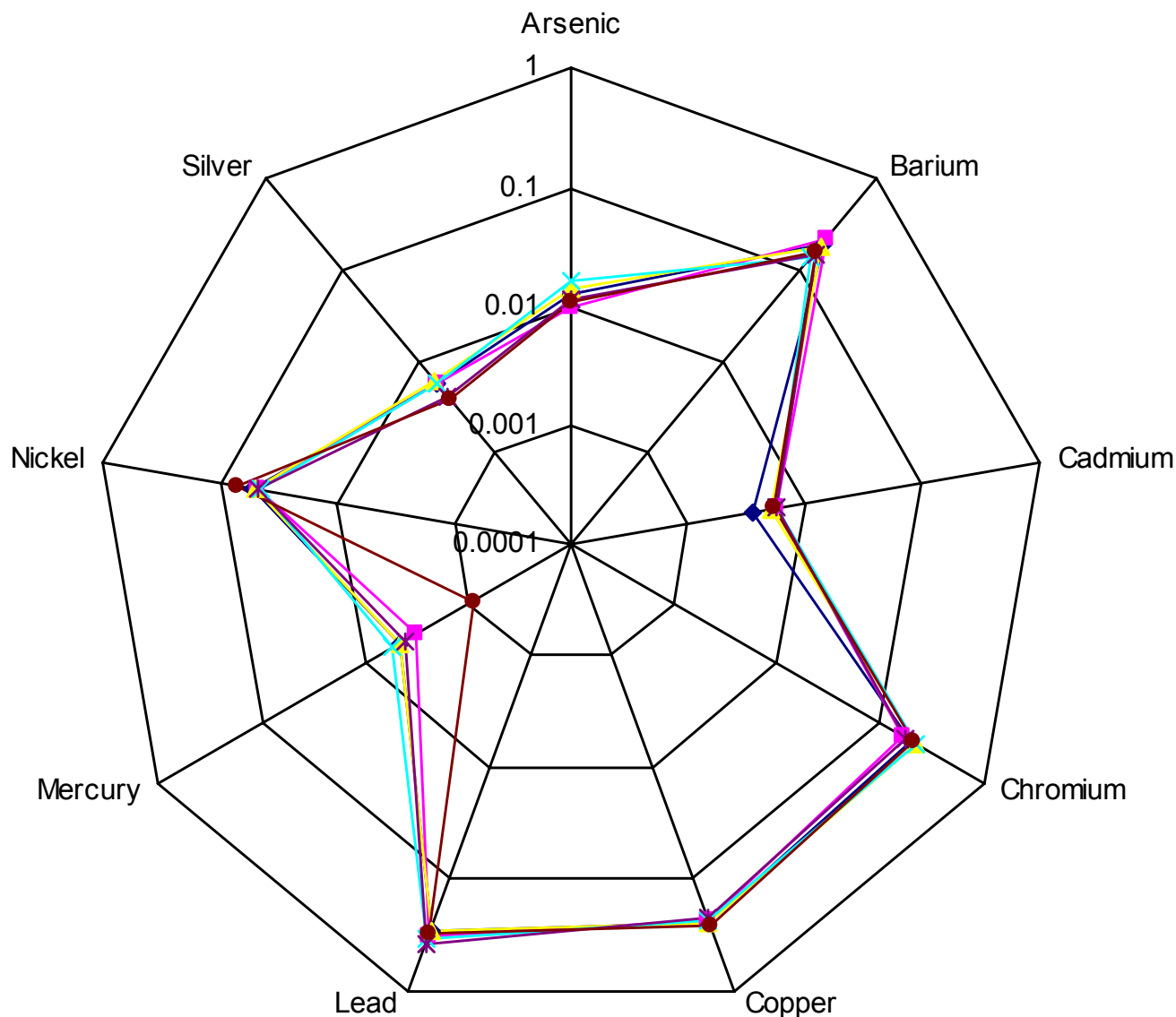
Figure 4-15e

February 2006
Draft

Comparison of Total DDT Concentrations in 1963, 1985, 1986, and 1995

Lower Passaic River Restoration Project

Figure 4-15f

February 2006
Draft
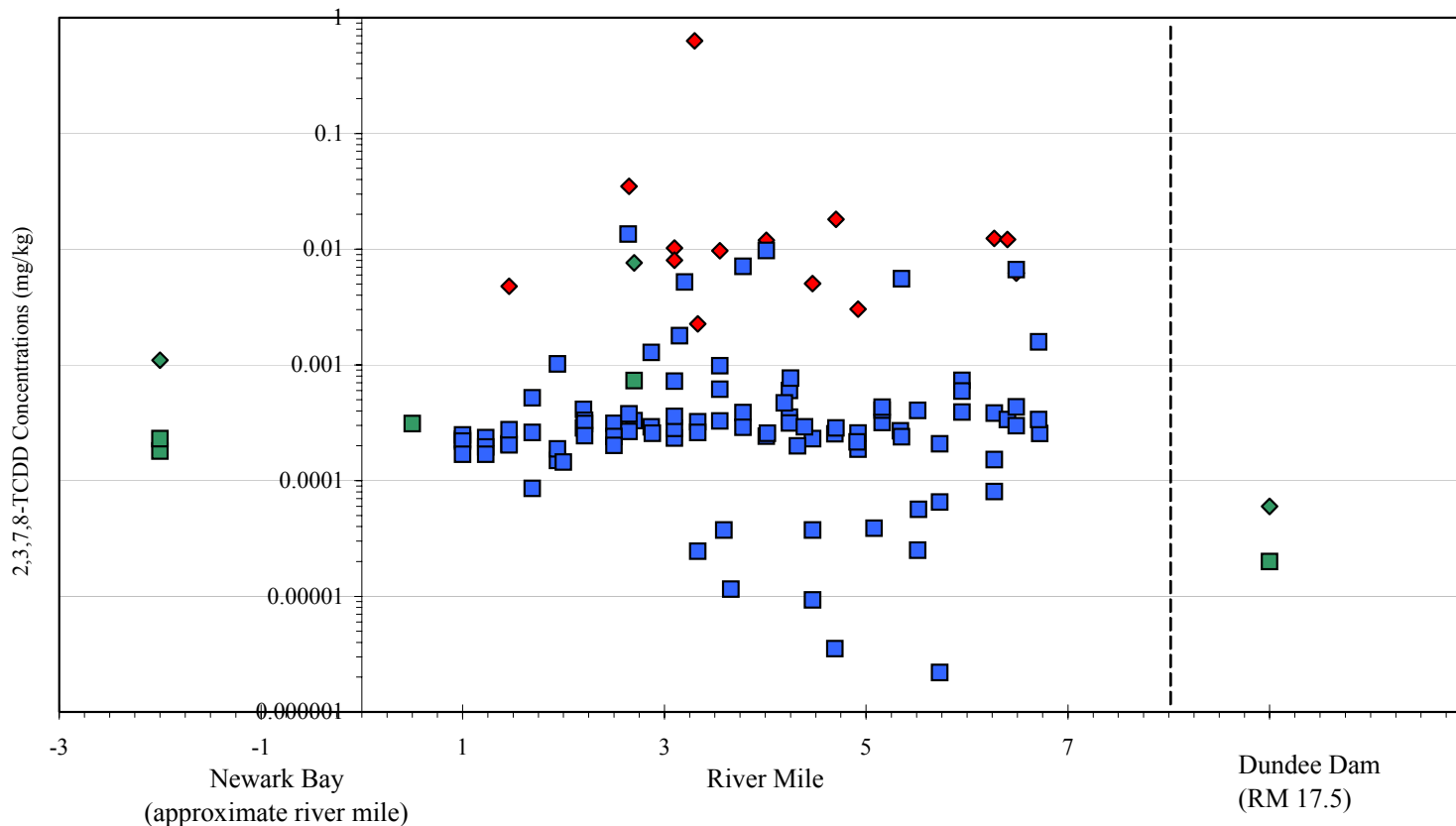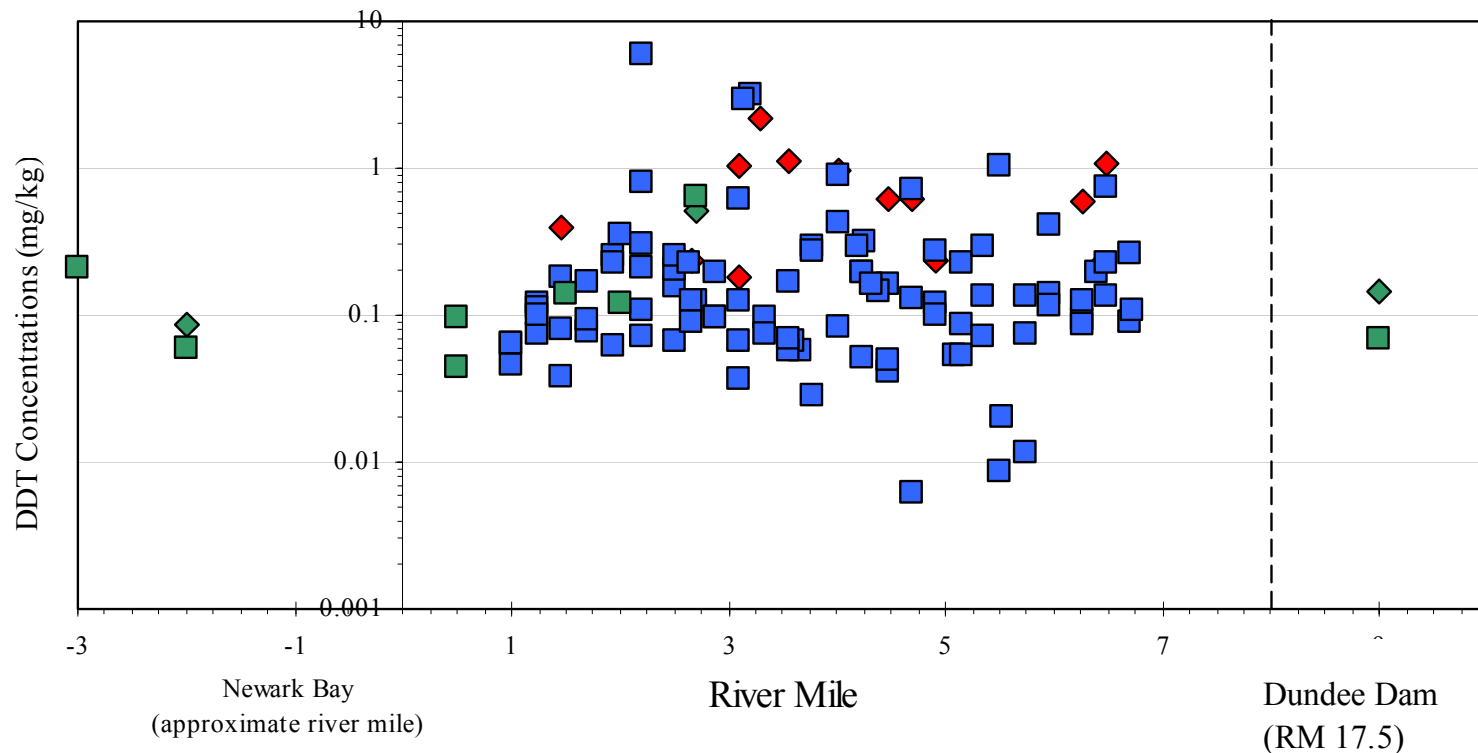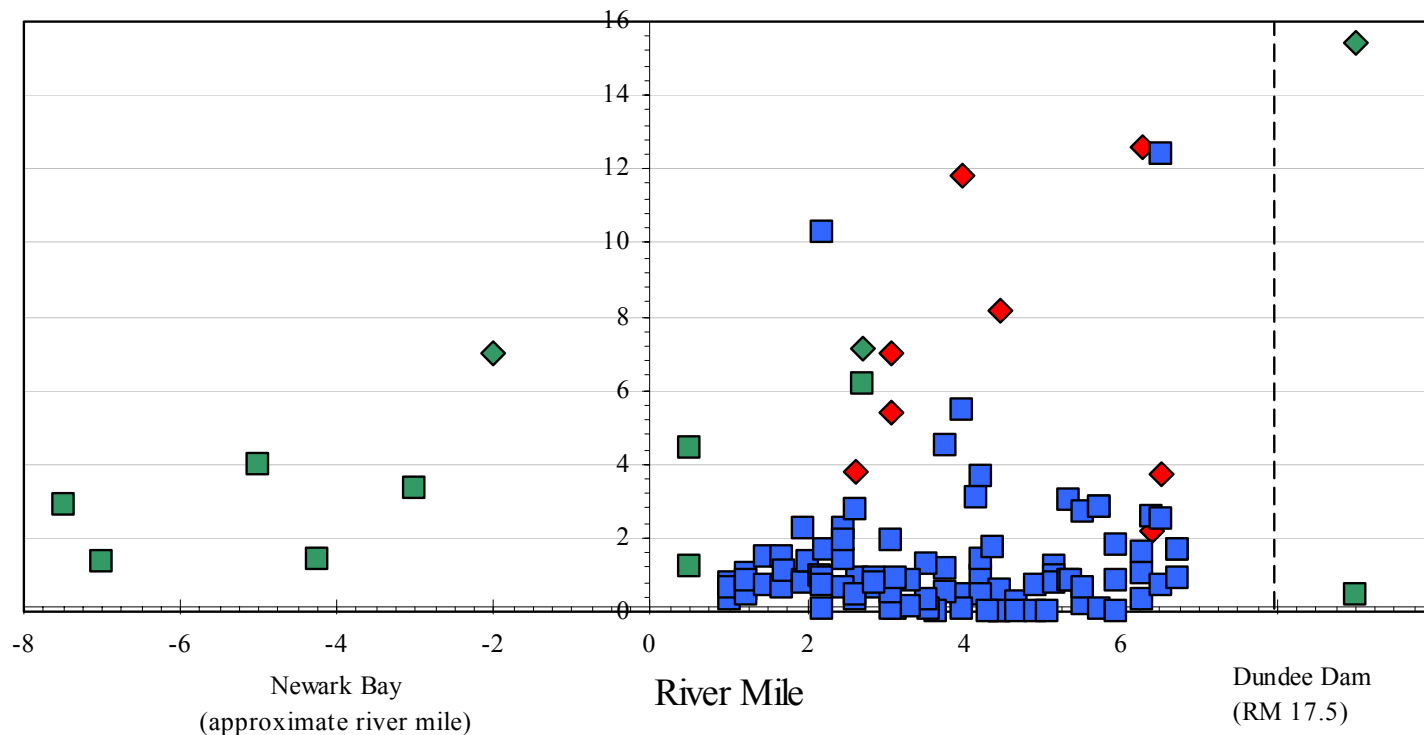
Legend

- ◆ Tierra Solutions, Inc (1963)
- ■ Tierra Solutions, Inc. (1995)
- ◆ Bopp et al., 1991a (1963)
- ■ Bopp er al., 1991a (1985-1986)

Location

Notes

Tierra Solutions Inc. Data Source:
PASSAIC 1995 RI Sampling Program (14 of the 95 locations), Tierra Solutions, Inc.

Interpolated concentrations calculated at the depth corresponding to the cesium-137 peak

Non-detect (lab qualifier containing a U) plotted as half the reported detection limit

Total PCB values are the sum of Aroclors 1248, 1254, and 1260

Bopp et al,. 1991a Data Source:
Sediment Sampling and Radionuclide and Chlorinated Hydrocarbon Analysis in Newark Bay and the Hackensack and Passaic Rivers, Bopp et al.

Concentration obtained from analysis of discrete core sections corresponding to the cesium-137 peak.

Total PCB concentrations are the sum of Aroclors 1242 and 1254.

Comparison of Total PCB Concentrations in 1963, 1985, 1986, and 1995

Lower Passaic River Restoration Project

Figure 4-15g

February 2006
Draft

MALCOLM PIRNIE

Arsenic

Silver

Barium

Nickel

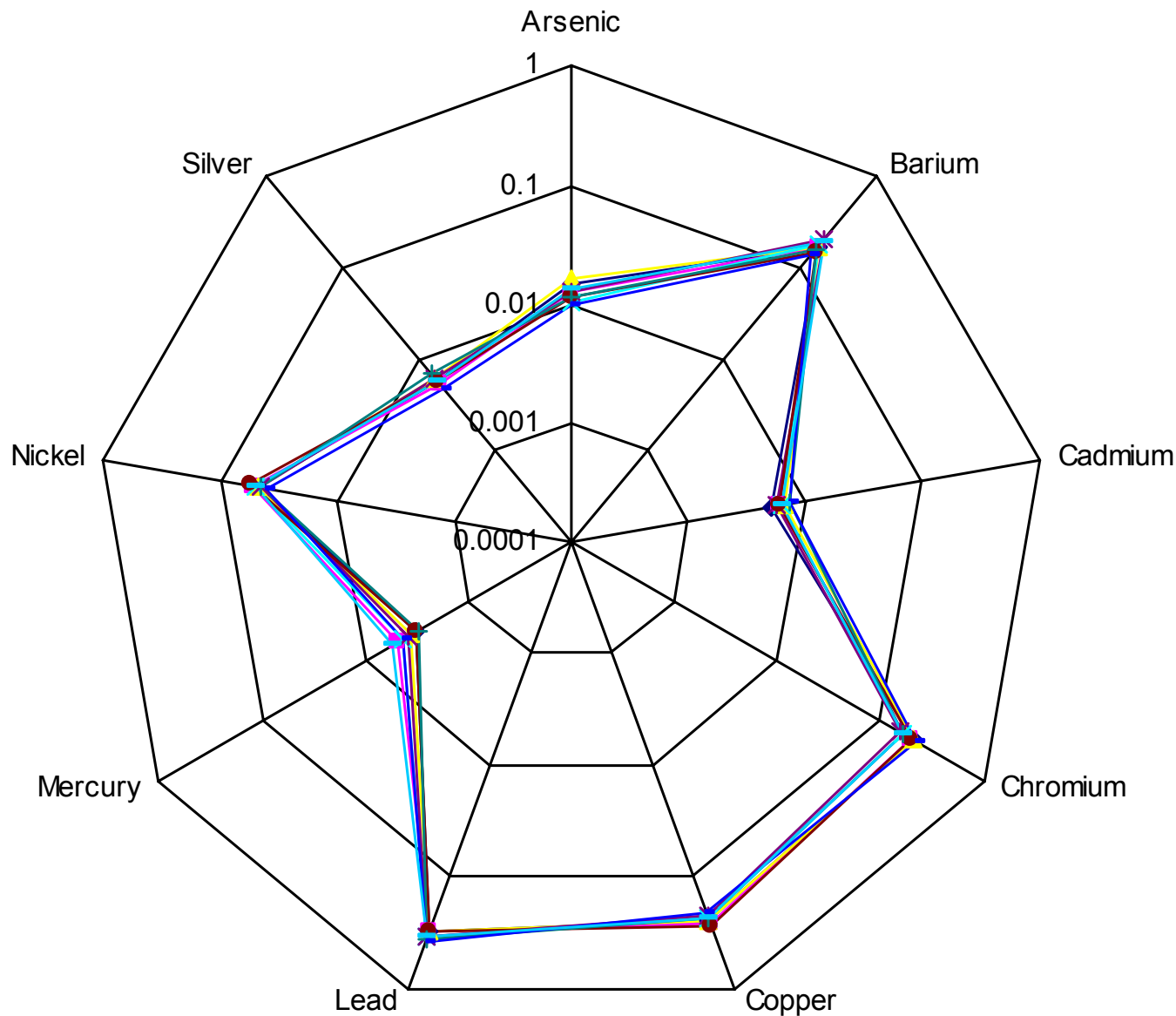Cadmium

Mercury

Chromium

Lead

Copper

1
0.1
0.01
0.001
0.0001

Radar Plot for Selected Metals
River Mile 1 to River Mile 2
Lower Passaic River Restoration Project

Figure 4-16a

February 2006
Draft

US Army Corps
of Engineers

MALCOLM
PIRNIE

Radar Plot for Selected Metals
River Mile 2 to River Mile 3
Lower Passaic River Restoration Project

Figure 4-16b

February 2006
Draft

Radar Plot for Selected Metals
River Mile 3 to River Mile 4
Lower Passaic River Restoration Project
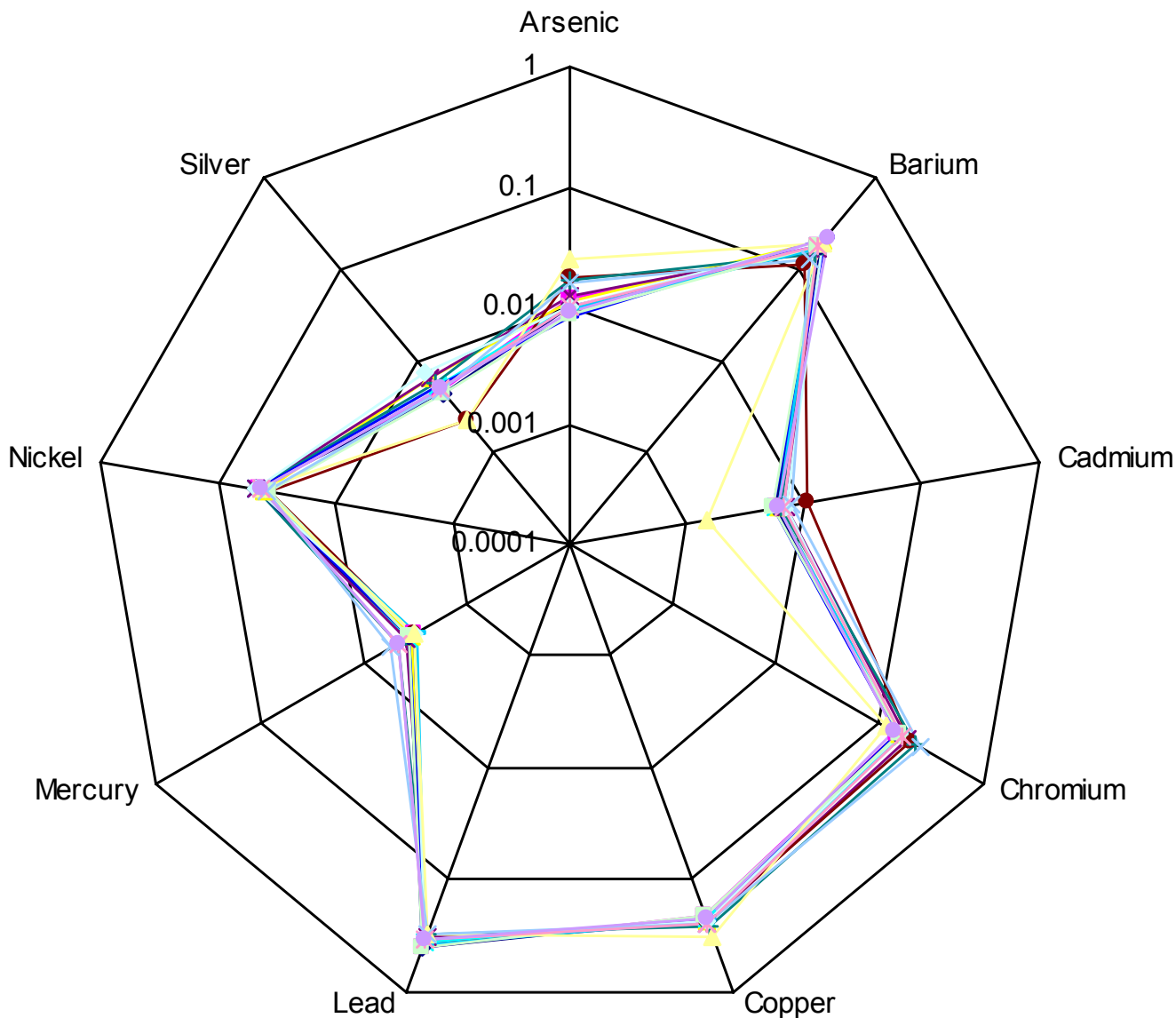
Figure 4-16c

February 2006
Draft

Radar Plot for Selected Metals
River Mile 4 to River Mile 5
Lower Passaic River Restoration Project

Figure 4-16d

February 2006
Draft

Legend

- TSI 240 / RM 4.01
- TSI 241 / RM 4.01
- TSI 242 / RM 4.02
- TSI 289 / RM 4.19
- TSI 243 / RM 4.24
- TSI 244 / RM 4.24
- TSI 245 / RM 4.24
- TSI 290 / RM 4.25
- TSI 291 / RM 4.32
- TSI 292 / RM 4.39
- TSI 292 dup / RM 4.39
- TSI 246 / RM 4.47
- TSI 248 / RM 4.47
- TSI 249 / RM 4.69
- TSI 251 / RM 4.7
- TSI 254 / RM 4.91
- TSI 253 / RM 4.92

Location

River Mile 4 to River Mile 5

Note:
Each metal in the radar plot is represented on its own axis, which radiates from the center point of the graph. Metal concentrations are plotted as a unitless mass fraction [concentration of the metal (ug/kg)/ total concentration (ug/kg)]. For clarity, a logarithmic scale is used. Lines connect all the values from a given sample.

Data Source: Tierra Solutions, Inc. 1995 Dataset. Results are from surface sediment samples(0 to 0.5 foot)
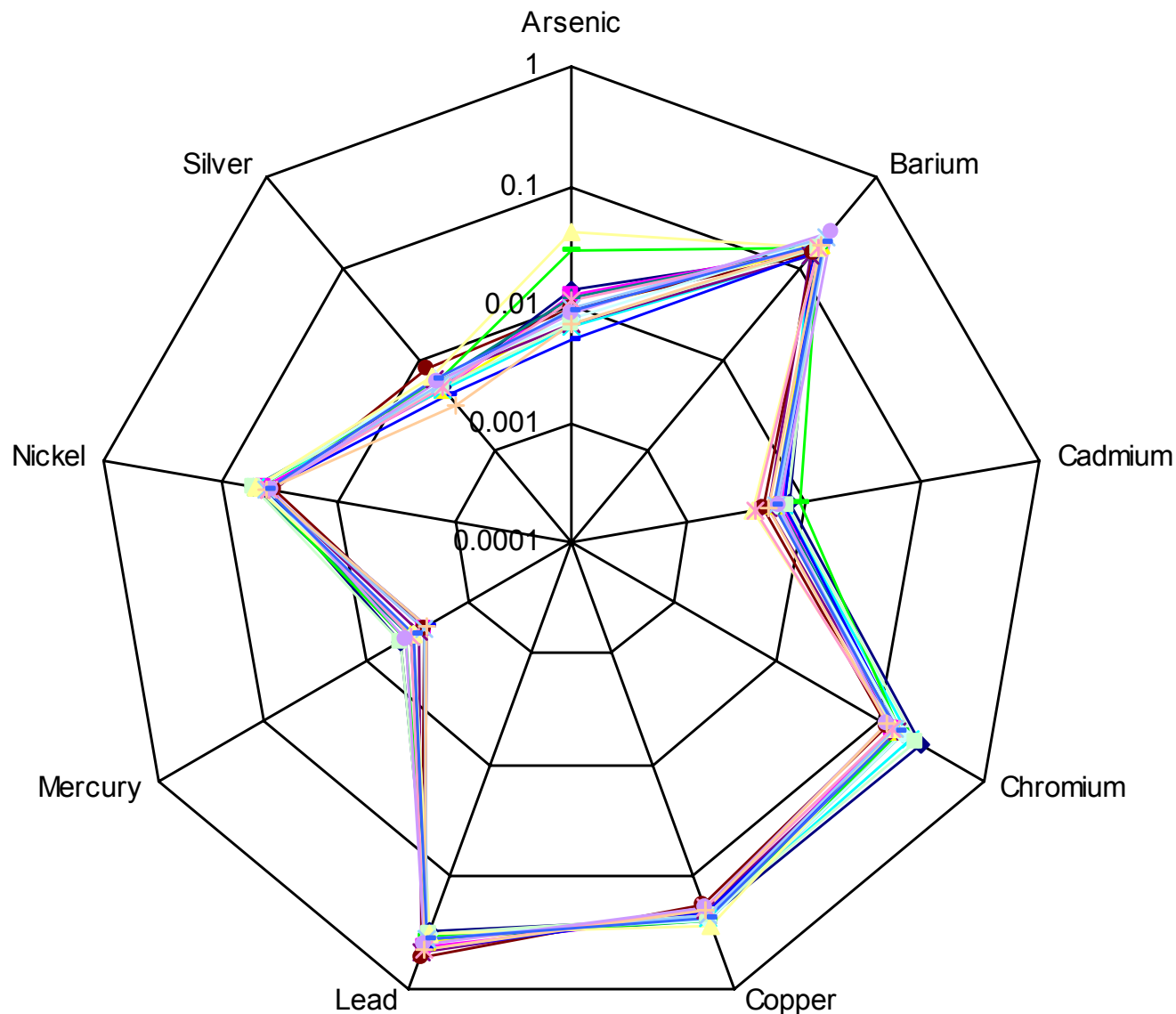
Radar Plot for Selected Metals
River Mile 5 to River Mile 6
Lower Passaic River Restoration Project

Figure 4-16e

February 2006
Draft

Radar Plot for Selected Metals
River Mile 6 to River Mile 7
Lower Passaic River Restoration Project

Figure 4-16f

February 2006
Draft

Legend

- TSI 272 / RM 6.27
- TSI 296 / RM 6.4
- TSI 273 / RM 6.49
- TSI 274 / RM 6.49
- TSI 275 / RM 6.49
- TSI 276 / RM 6.71
- TSI 278 / RM 6.71

Location

River Mile 6 to River Mile 7

Note:
Each metal in the radar plot is represented on its own axis, which radiates from the center point of the graph. Metal concentrations are plotted as a unitless mass fraction [concentration of the metal (ug/kg)/ total concentration (ug/kg)]. For clarity, a logarithmic scale is used. Lines connect all the values from a given sample.

Data Source: Tierra Solutions, Inc. 1995 Dataset. Results are from surface sediment samples(0 to 0.5 foot)
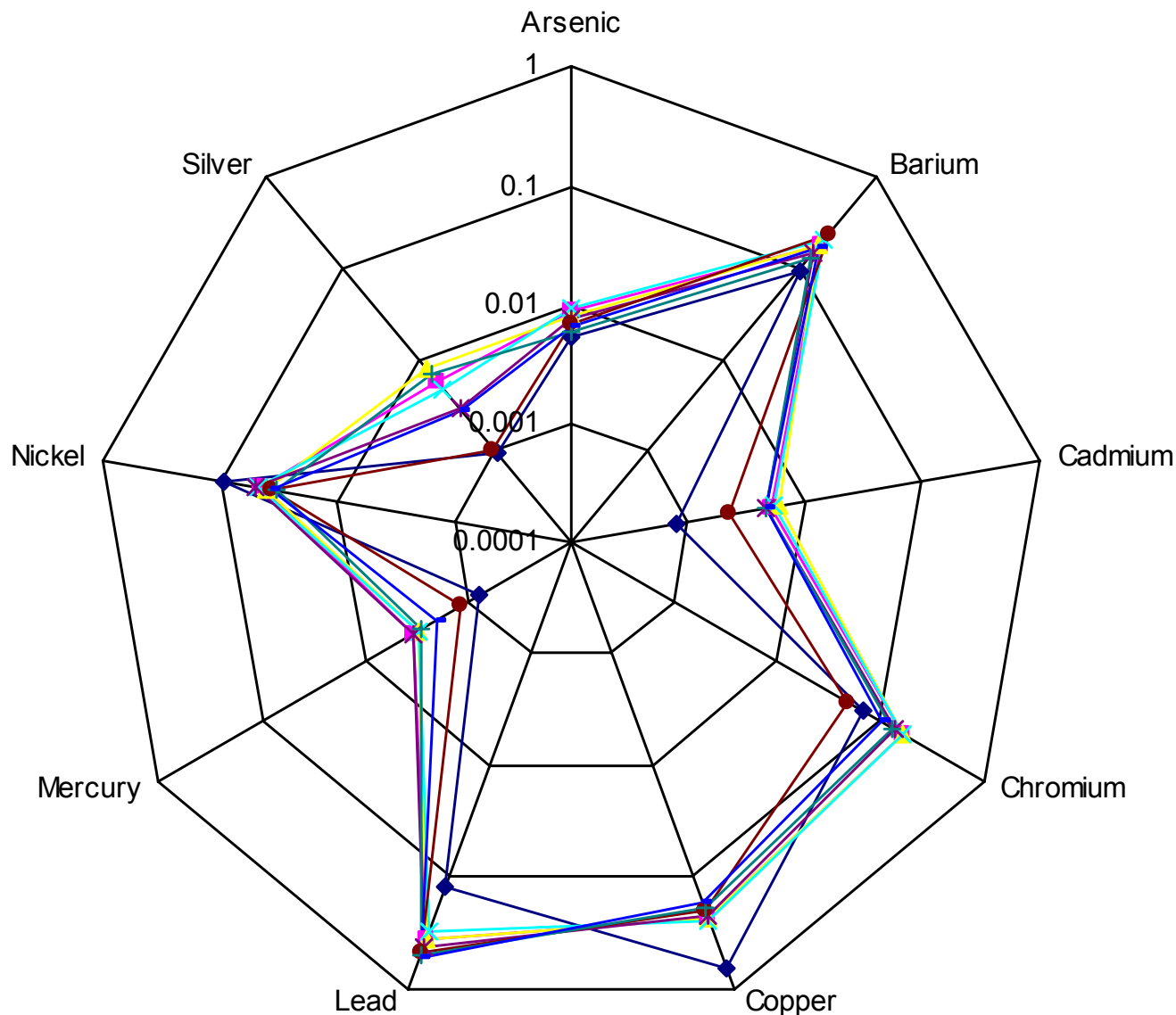
MALCOLM PIRNIE

Radar Plot for Selected Metals
River Mile 1 to River Mile 7

Lower Passaic River Restoration Project

Figure 4-16g

February 2006
Draft

Legend

✳— TSI 206 / RM 1.23
+— TSI 226 / RM 2.88
■— TSI 237 / RM 3.78
✳— TSI 240 / RM 4.01
✳— TSI 257 / RM 5.16
✳— TSI 273 / RM 6.49

Location

River Mile 1 to River Mile 7

Note:
Each metal in the radar plot is represented on its own axis, which radiates from the center point of the graph.Metal concentrations are plotted as a unitless mass fraction [concentration of the metal (ug/kg)/ total concentration (ug/kg)]. For clarity, a logarithmic scale is used. Lines connect all the values from a given sample.

Data Source: Tierra Solutions, Inc. 1995 Dataset. Results are from surface sediment samples(0 to 0.5 foot)
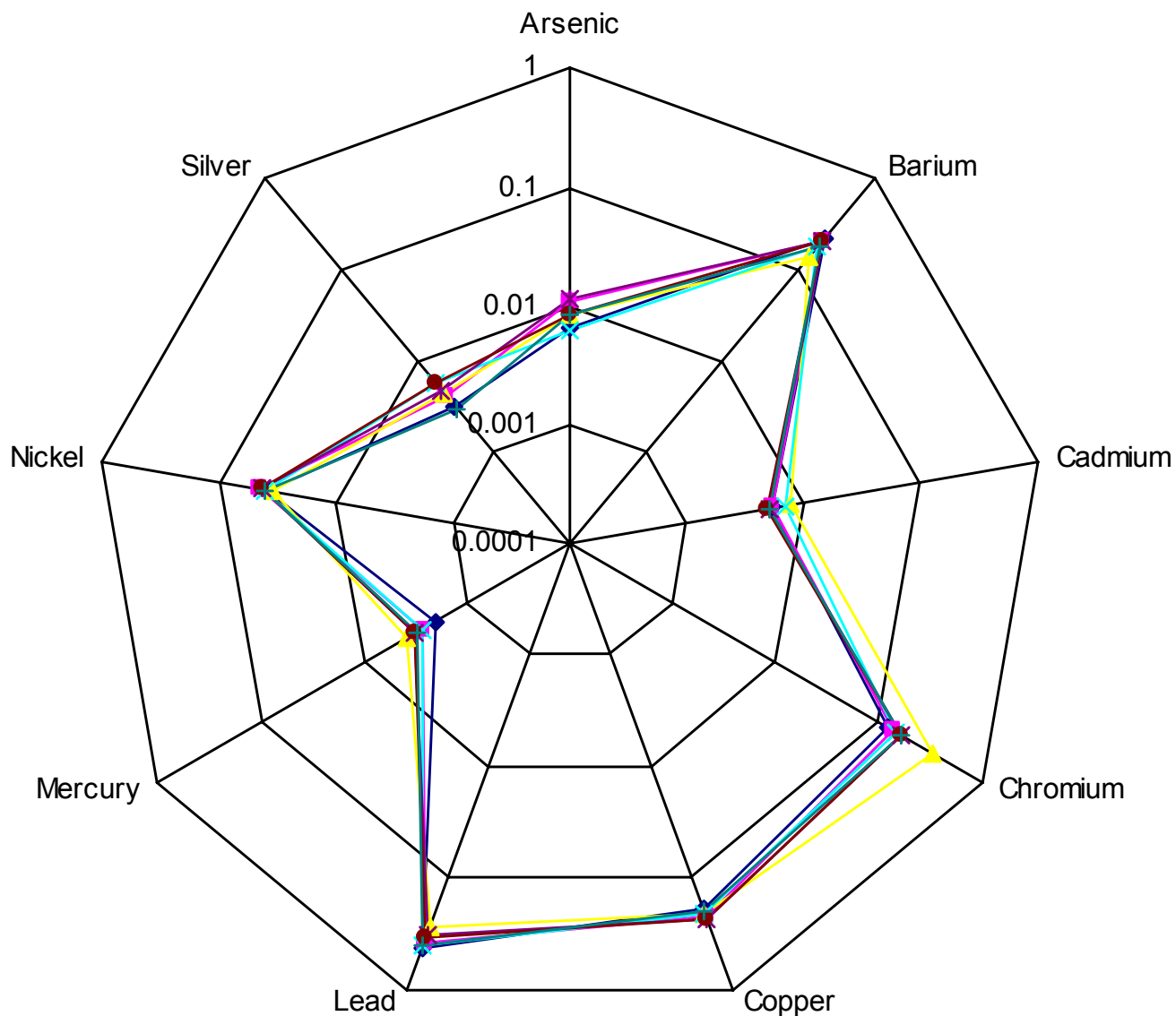
Cadmium

1.000

0.100

0.010

0.001

0.000

Mercury

Copper

Lead

Location

River Mile 1 to River Mile 3

Notes

Each metal in the radar plot is represented on its own axis, which radiates from the center point of the graph. Metal concentrations are plotted as a unitless mass fraction [concentration of the metal (ug/kg)/ total concentration (ug/kg)]. For clarity, a logarithmic scale is used. Lines connect all the values from a given sample.

Data Source:
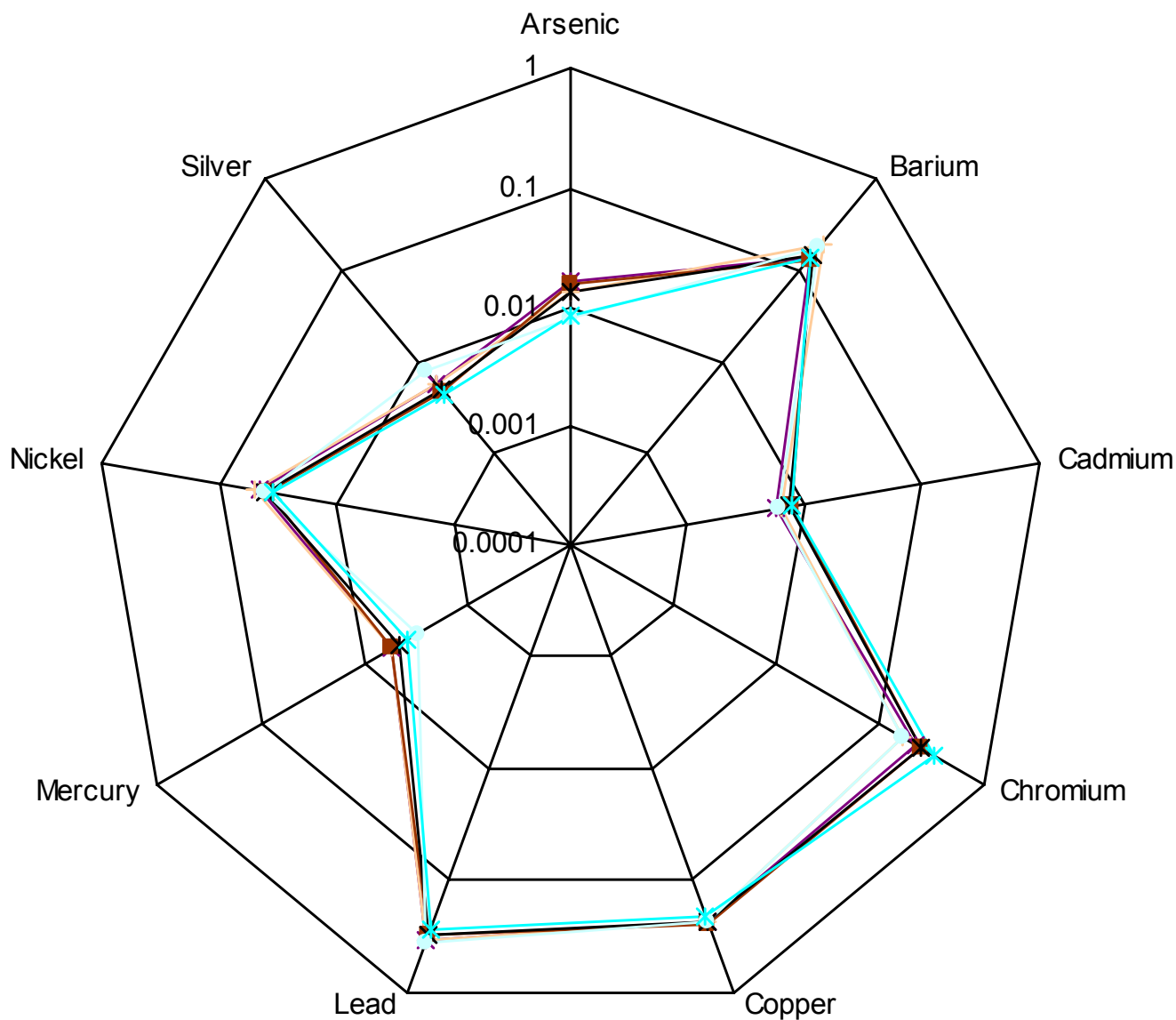Tierra Solutions, Inc. 1995 Dataset. Results are from surface sediment samples (0 to 0.5 foot)

Radar Plot for Cadmium, Copper, Lead, and Mercury,
River Mile 1 to River Mile 3

Lower Passaic River Restoration Project

Figure 4-17a

February 2006
Draft

US Army Corps
of Engineers®

MALCOLM
PIRNIE

Radar Plot for Cadmium, Copper, Lead, and Mercury, River Mile 4 to River Mile 5

Lower Passaic River Restoration Project

Figure 4-17b

February 2006
Draft

Legend

- TSI 240 / RM 4.01
- TSI 241 / RM 4.01
- TSI 242 / RM 4.02
- TSI 289 / RM 4.19
- TSI 243 / RM 4.24
- TSI 244 / RM 4.24
- TSI 245 / RM 4.24
- TSI 290 / RM 4.25
- TSI 291 / RM 4.32
- TSI 292 / RM 4.39
- TSI 292 dup / RM 4.39
- TSI 246 / RM 4.47
- TSI 248 / RM 4.47
- TSI 249 / RM 4.69
- TSI 251 / RM 4.7
- TSI 254 / RM 4.91
- TSI 253 / RM 4.92

Location

River Mile 4 to River Mile 5

Notes

Each metal in the radar plot is represented on its own axis, which radiates from the center point of the graph. Metal concentrations are plotted as a unitless mass fraction [concentration of the metal (ug/kg)/ total concentration (ug/kg)]. For clarity, a logarithmic scale is used. Lines connect all the values from a given sample.

Data Source:
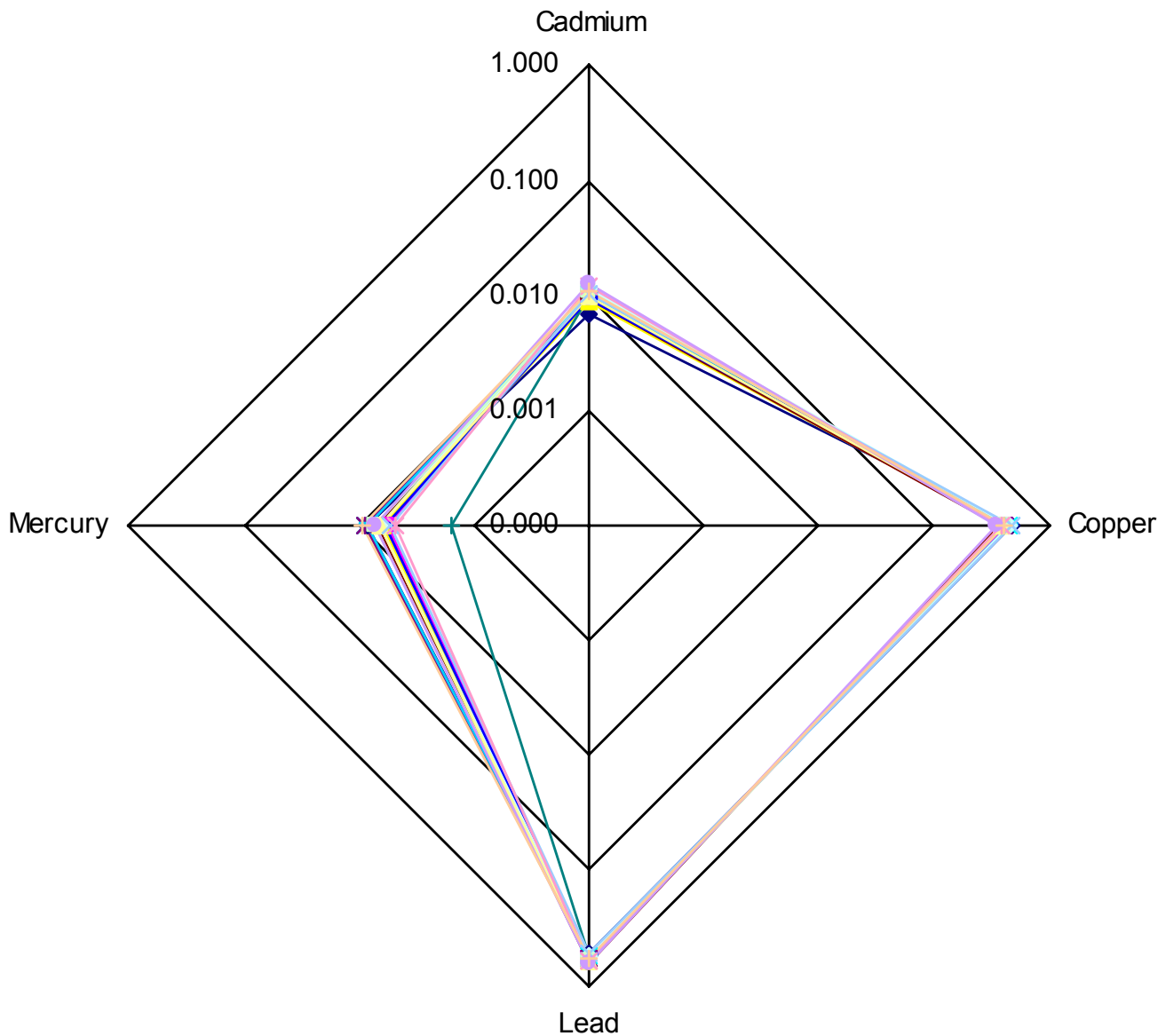Tierra Solutions, Inc. 1995 Dataset. Results are from surface sediment samples (0 to 0.5 foot)

Cadmium

1.000

0.100

0.010

0.001

0.000

Mercury

Copper

Lead

Radar Plot for Cadmium, Copper, Lead, and Mercury,
River Mile 6 to River Mile 7

Lower Passaic River Restoration Project

Figure 4-17c

February 2006
Draft
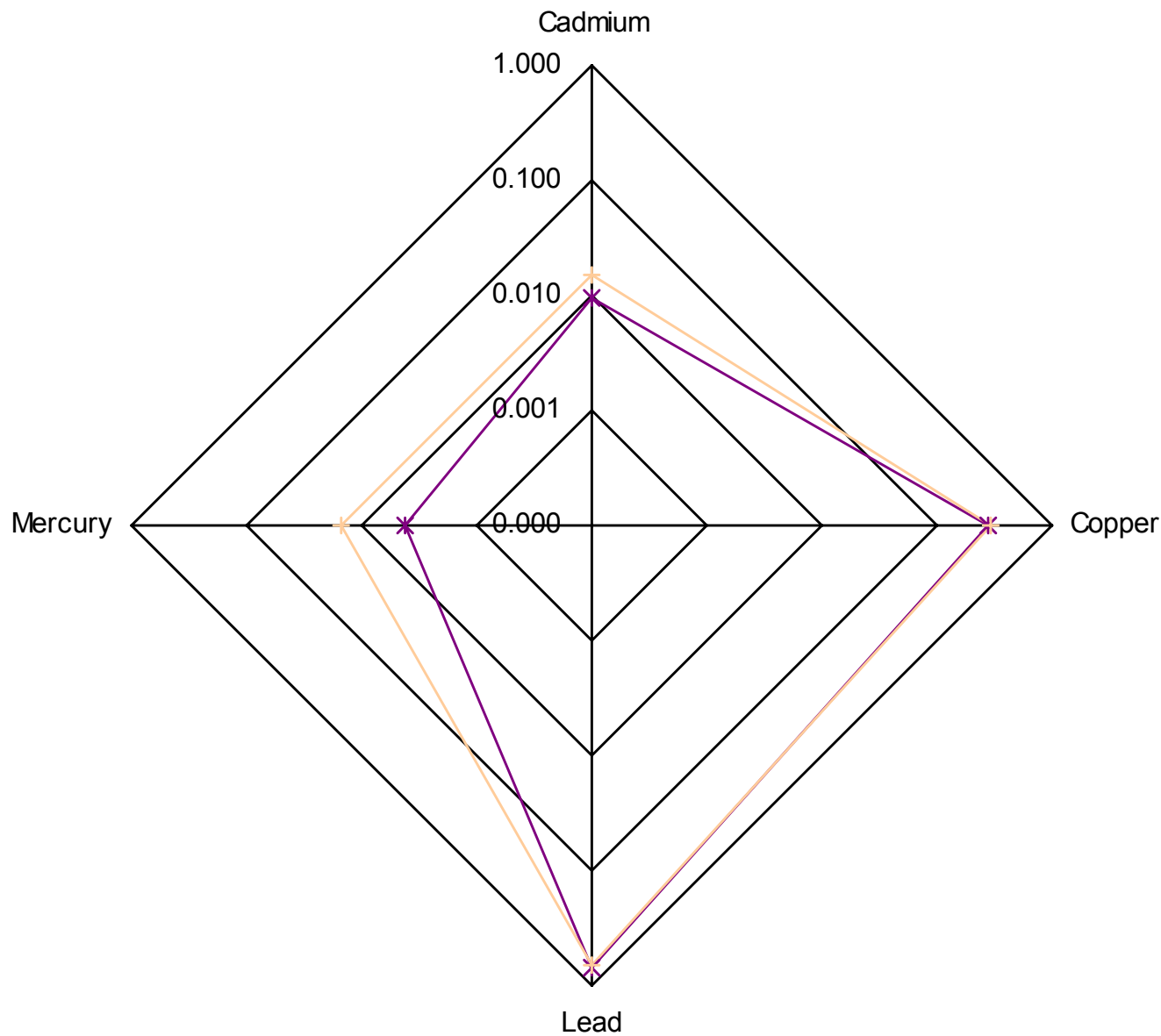
Cadmium

1.000

0.100

0.010

0.001

0.000

Mercury

Copper

Lead

US Army Corps of Engineers®
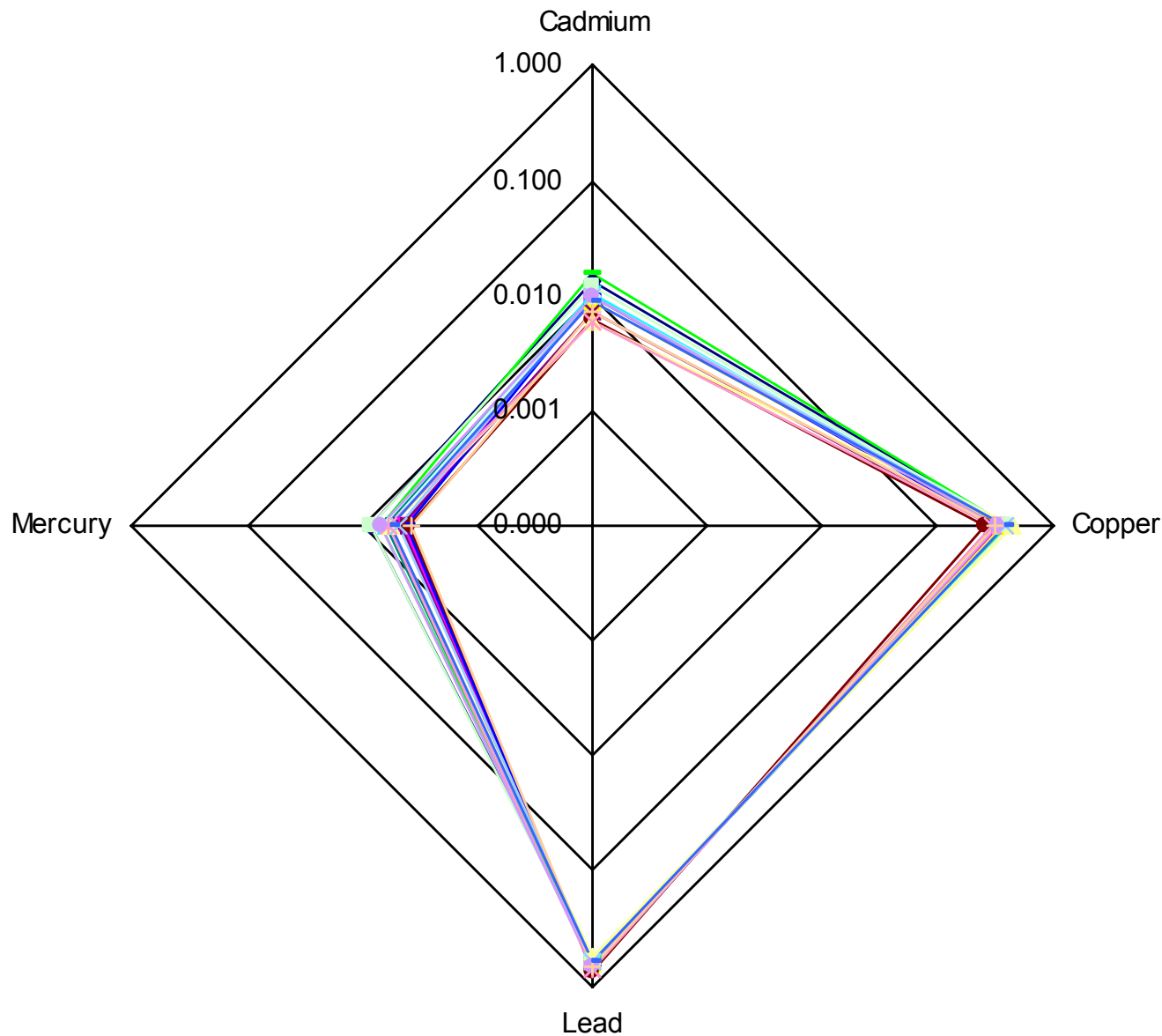
Radar Plot for Cadmium, Copper, Lead, and Mercury, Dundee Dam

Lower Passaic River Restoration Project

Figure 4-17d

February 2006
Draft
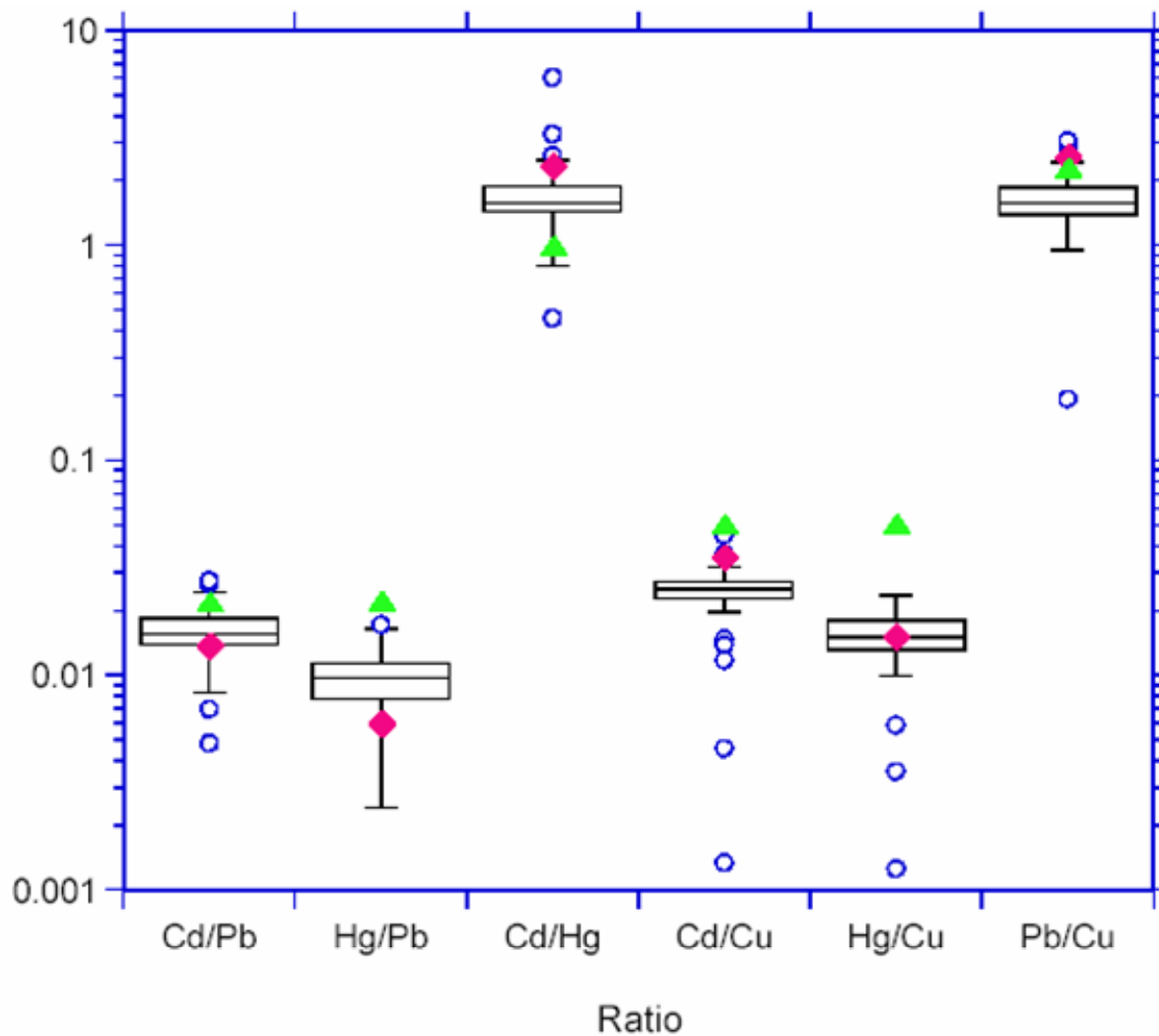
MALCOLM PIRNIE

Metal Ratios in Passaic River Sediments

Figure 4-18

February 2006
Draft
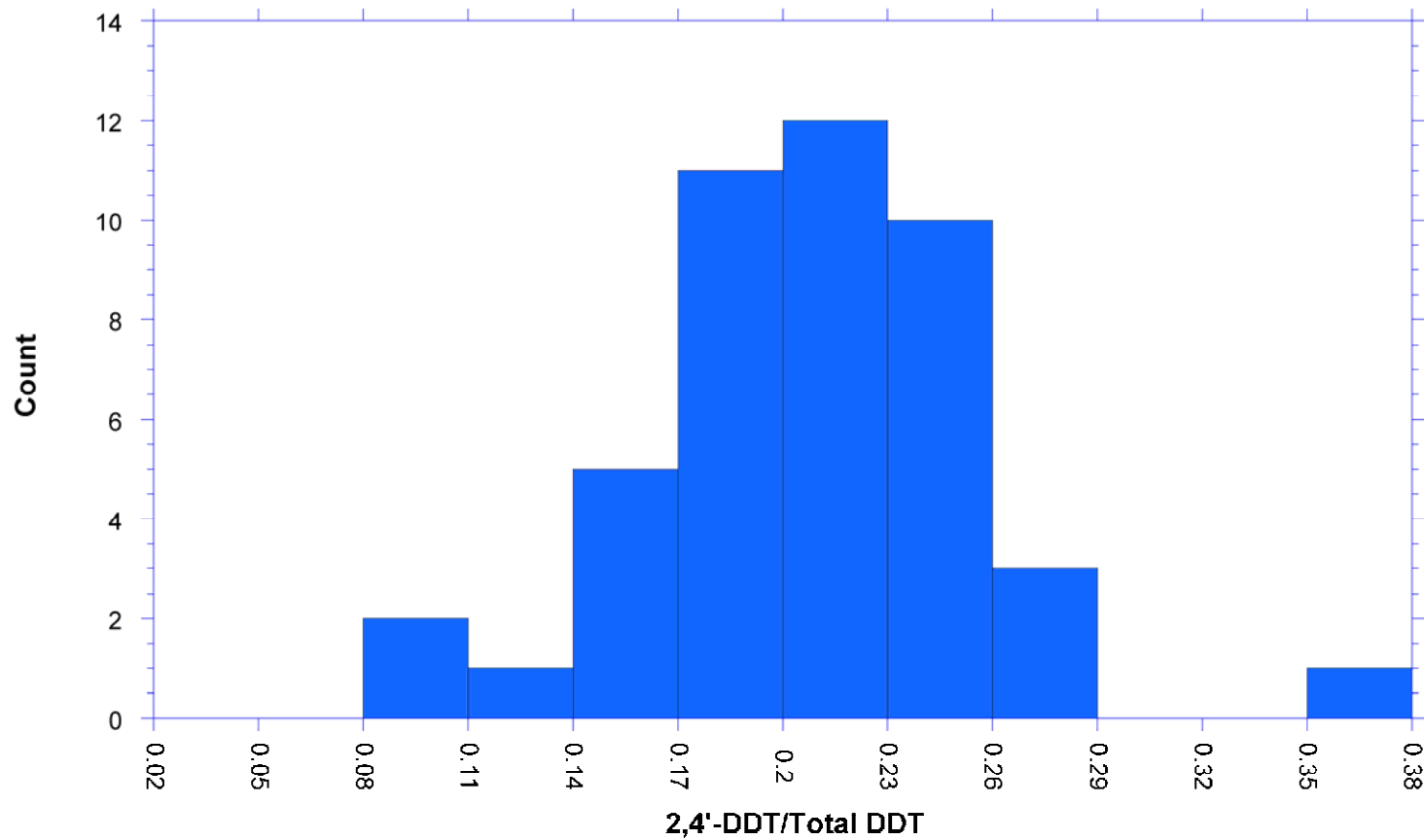
Lower Passaic River Restoration Project

DDT Fingerprint in the Passaic River

Figure 4-19

February 2006
Draft

Lower Passaic River Restoration Project

Total PAH Concentration vs. Mid-Depth of Sediment Core

Lower Passaic River Restoration Project

Figure 4-20

February 2006
Draft
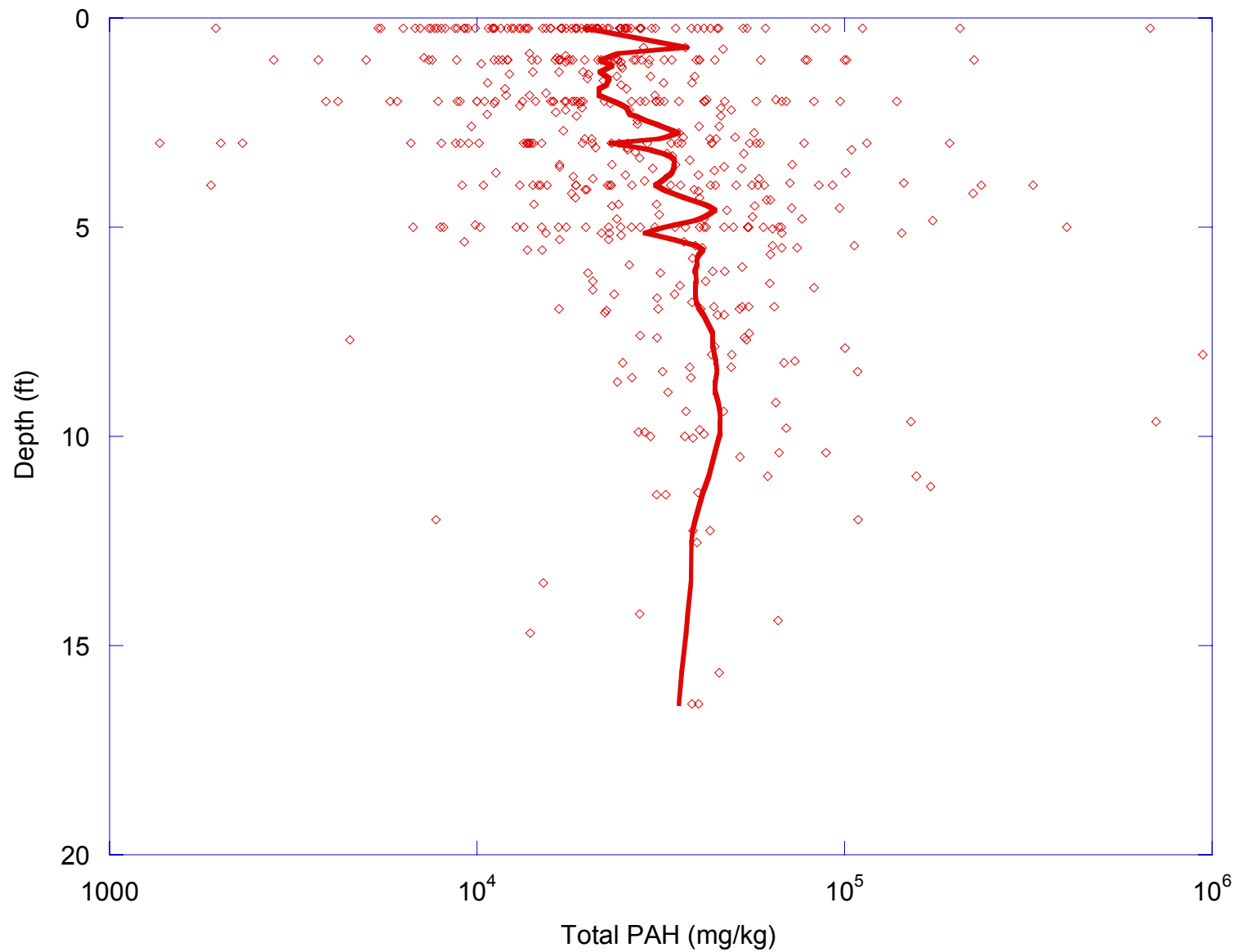
Legend

Location

River Mile 1 to River Mile 7

Notes

Trendline represents the weighted curve fit.
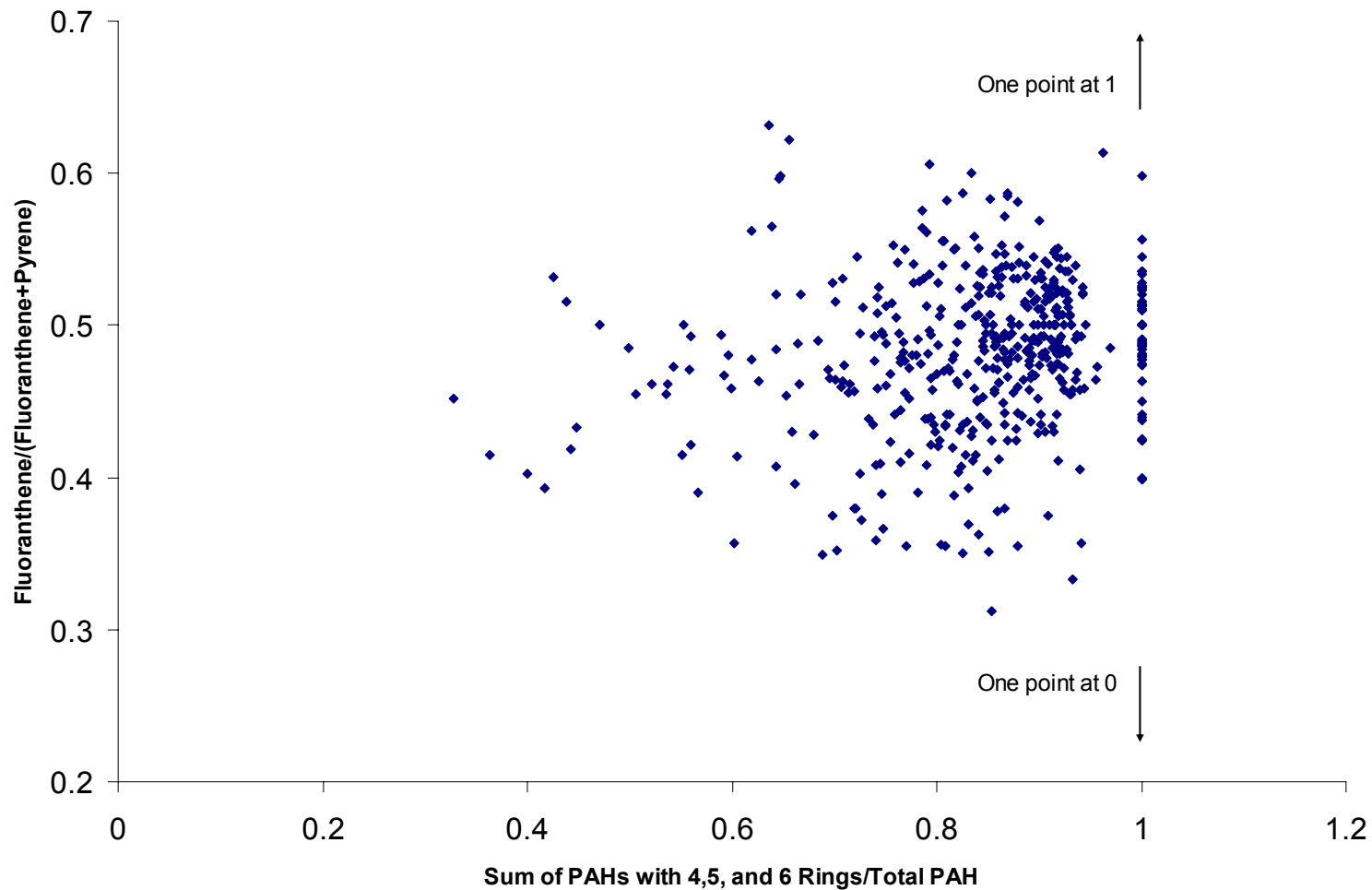
Legend

Location

River Mile 1 to River Mile 7

Notes

Data Source:
Tierra Solutions, Inc.,
1995 Dataset
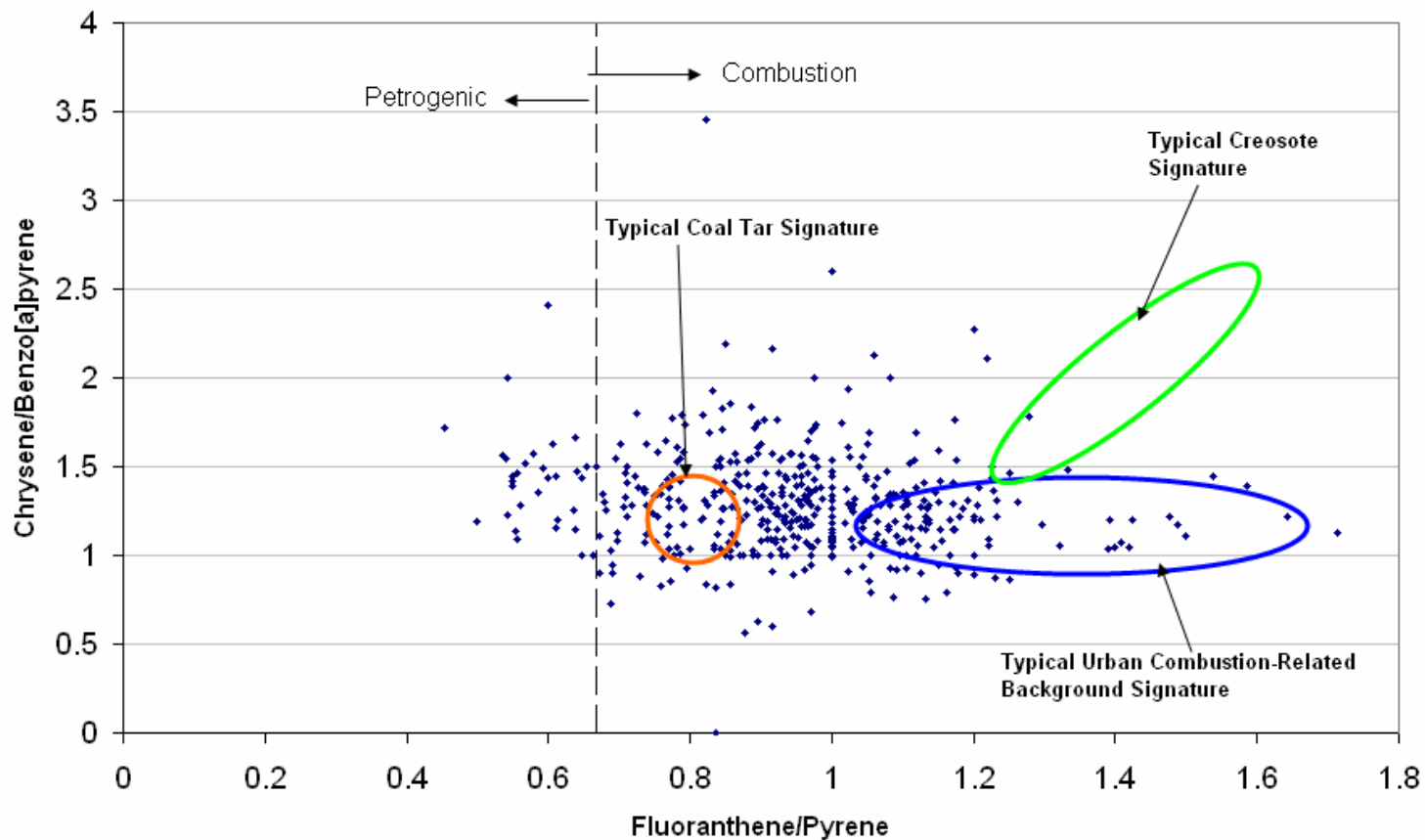
Double Ratio Analysis: Passaic River Sediment PAH
Compared to Costa and Sauer (2005) Source Signatures

Lower Passaic River Restoration Project

Figure 4-22a

February 2006
Draft
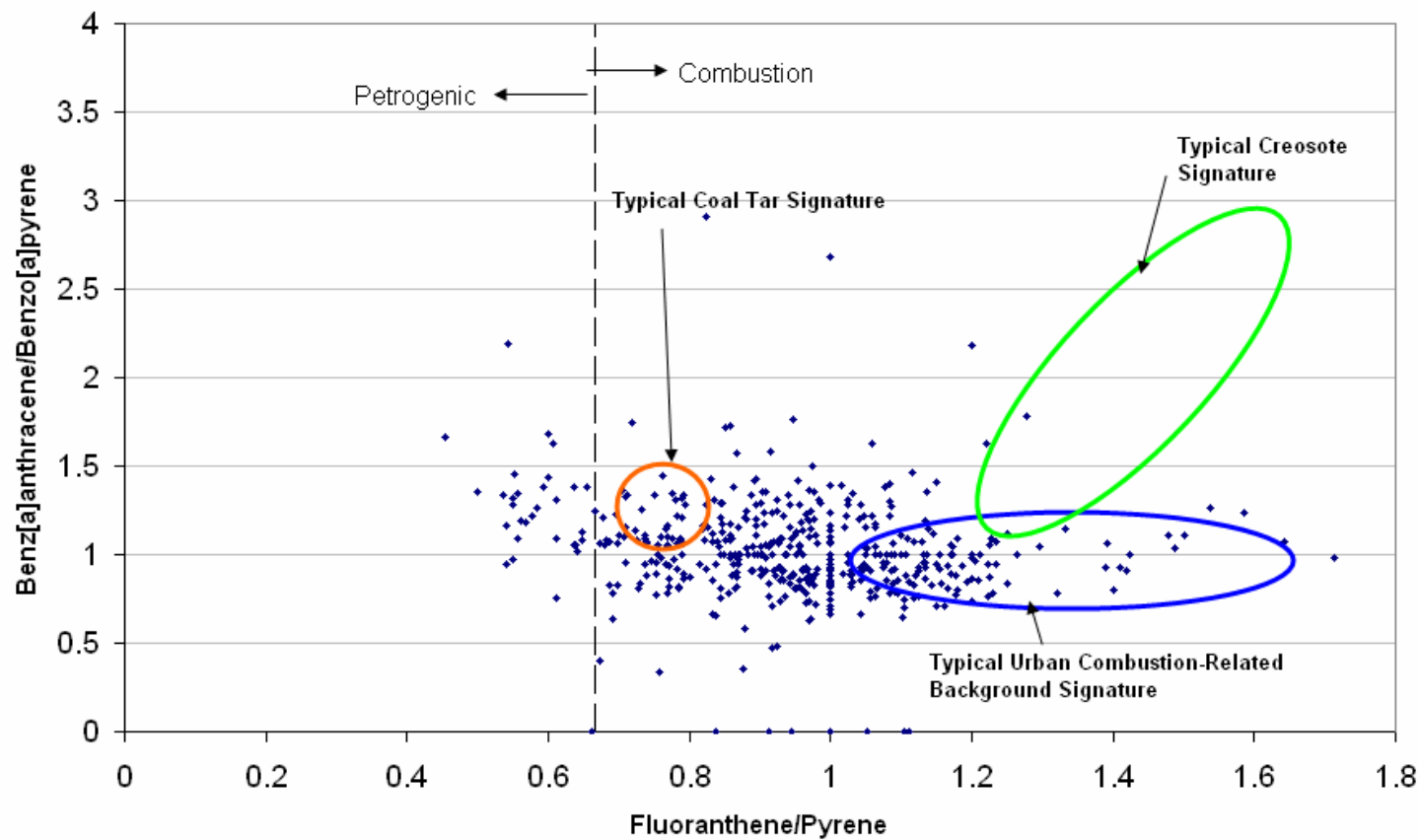
MALCOLM
PIRNIE

Double Ratio Analysis: Passaic River Sediment PAH Compared to Costa and Sauer (2005) Source Signatures

Lower Passaic River Restoration Project

Figure 4-22b

February 2006
Draft
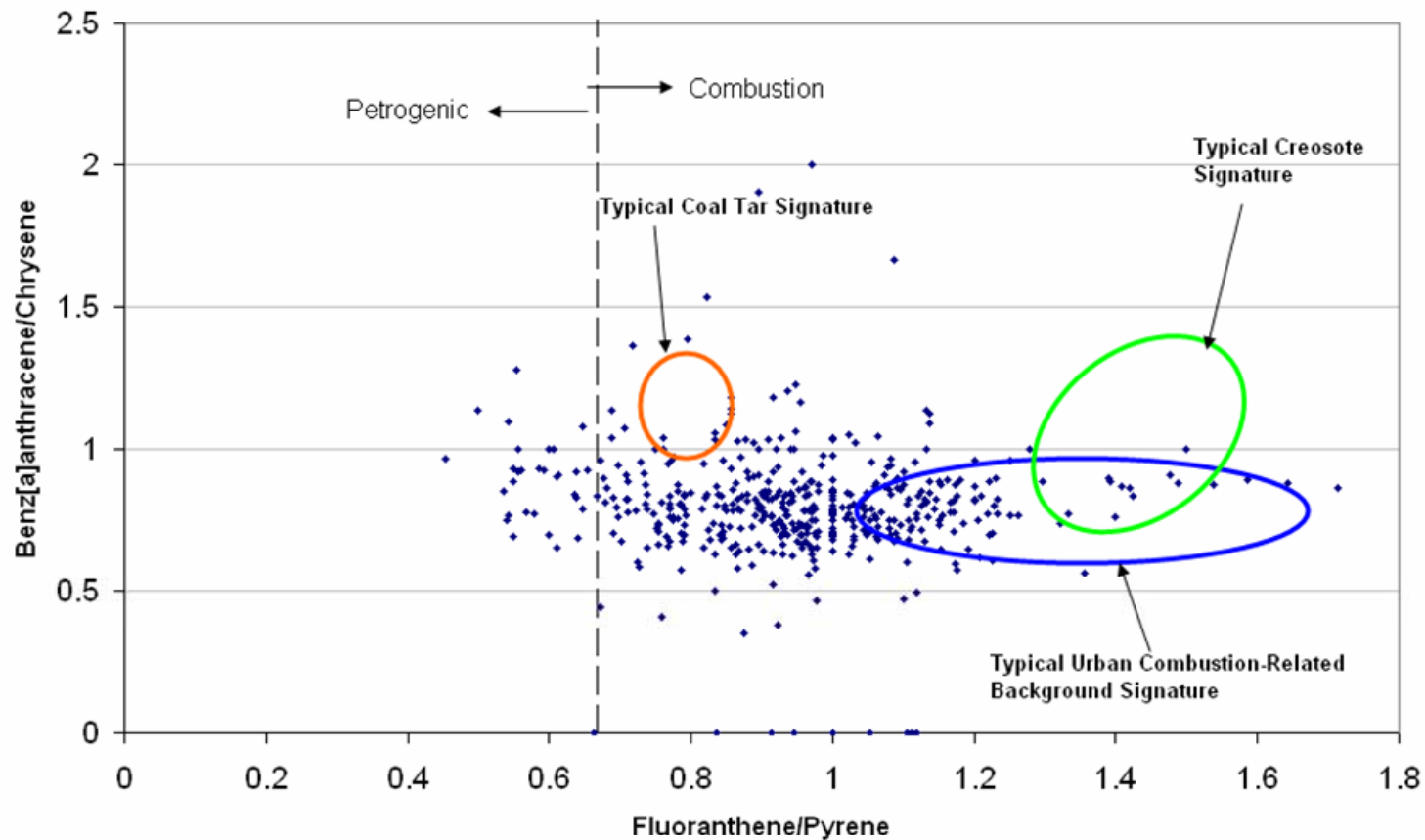
Double Ratio Analysis: Passaic River Sediment PAH Compared to Costa and Sauer (2005) Source Signatures

Lower Passaic River Restoration Project

Figure 4-22c

February 2006
Draft
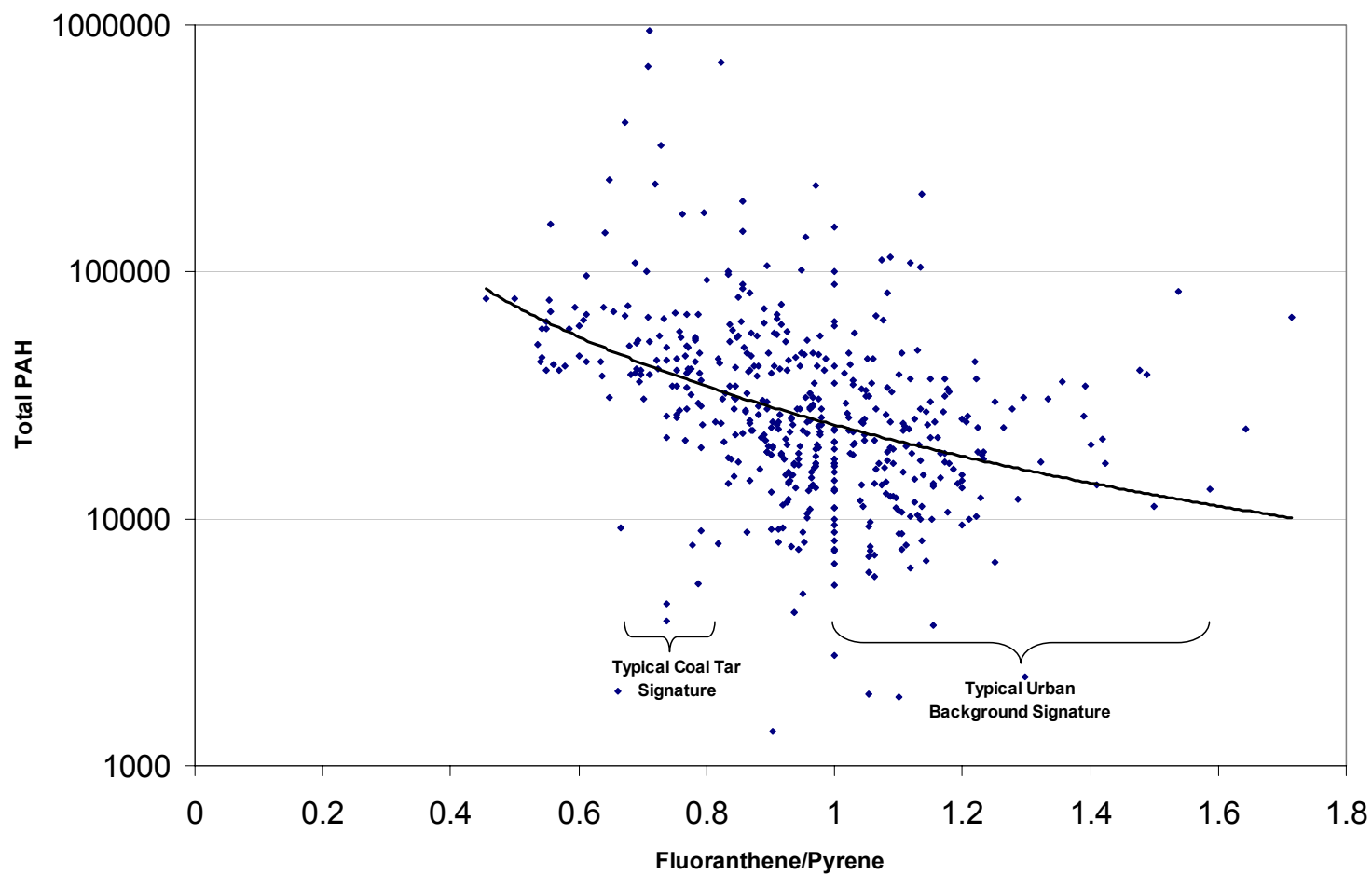
Total PAH vs. Fluoranthene/Pyrene Ratio

Figure 4-23

February 2006
Draft

Lower Passaic River Restoration Project

Legend

Location

Notes

Figure 4-24a

PAH Principal Component Analysis – Principal Component 1

Lower Passaic River Restoration Project

February 2006
Draft

PAH Principal Component Analysis – Principal Component 2

Lower Passaic River Restoration Project

Figure 4-24b

February 2006
Draft

PAH Principal Component Analysis – Principal Component 3

Figure 4-24c

February 2006
Draft

Lower Passaic River Restoration Project

Lowe et al. (2005) Solids Balance

Arthur Kill
Passaic River
Hackensack River
CSO/WWTP
Kill Van Kull
Atmosphere

Revised Solids Balance

Arthur Kill
Passaic River
Hackensack River
CSO/WWTP
Atmosphere
Kill Van Kull

2,3,7,8-TCDD Mass Balance

Arthur Kill
Kill Van Kull
Hackensack River
Passaic River

Mercury "Balance"
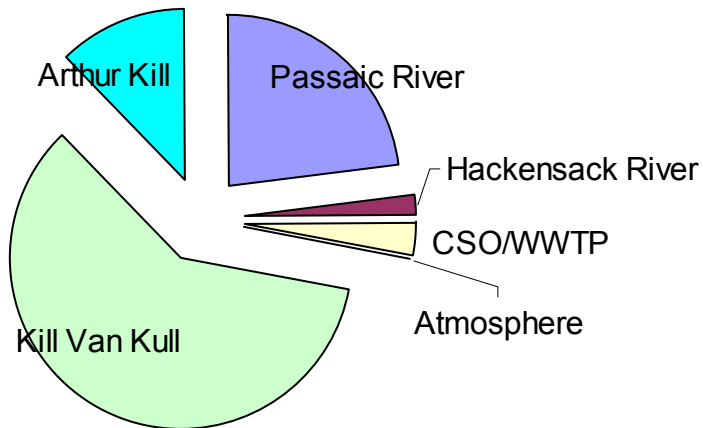
Passaic River
Hackensack River
"Missing" Hg
Kill Van Kull
Arthur Kill
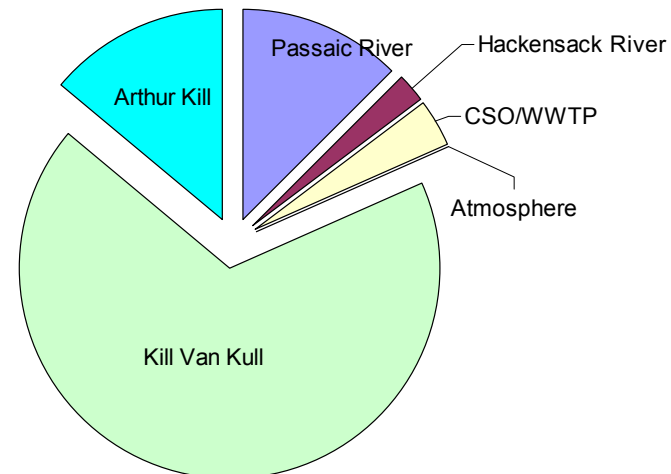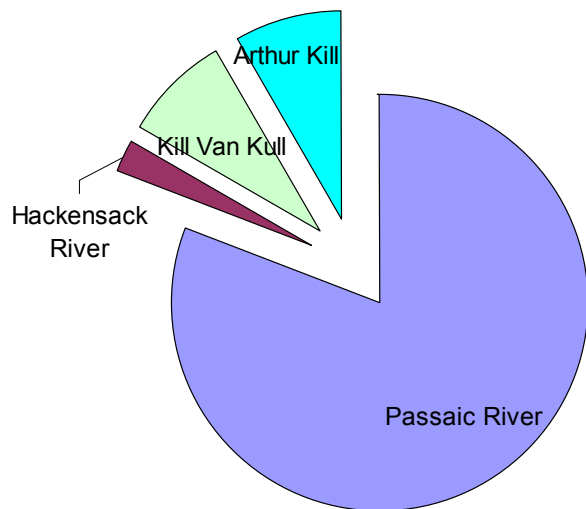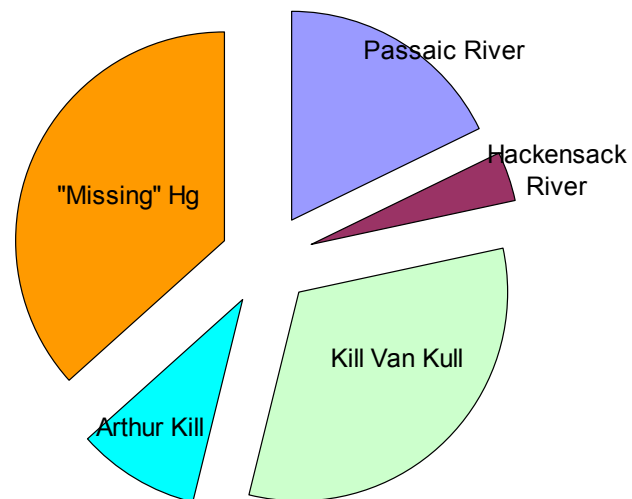
Mass Balance Results for Newark Bay

Lower Passaic River Restoration Project

Figure 4-25

February 2006
Draft

US Army Corps of Engineers

MALCOLM PIRNIE

Legend

Thickness of Silt (cm)

600
550
500
450
400
350
300
250
200
150
100
50
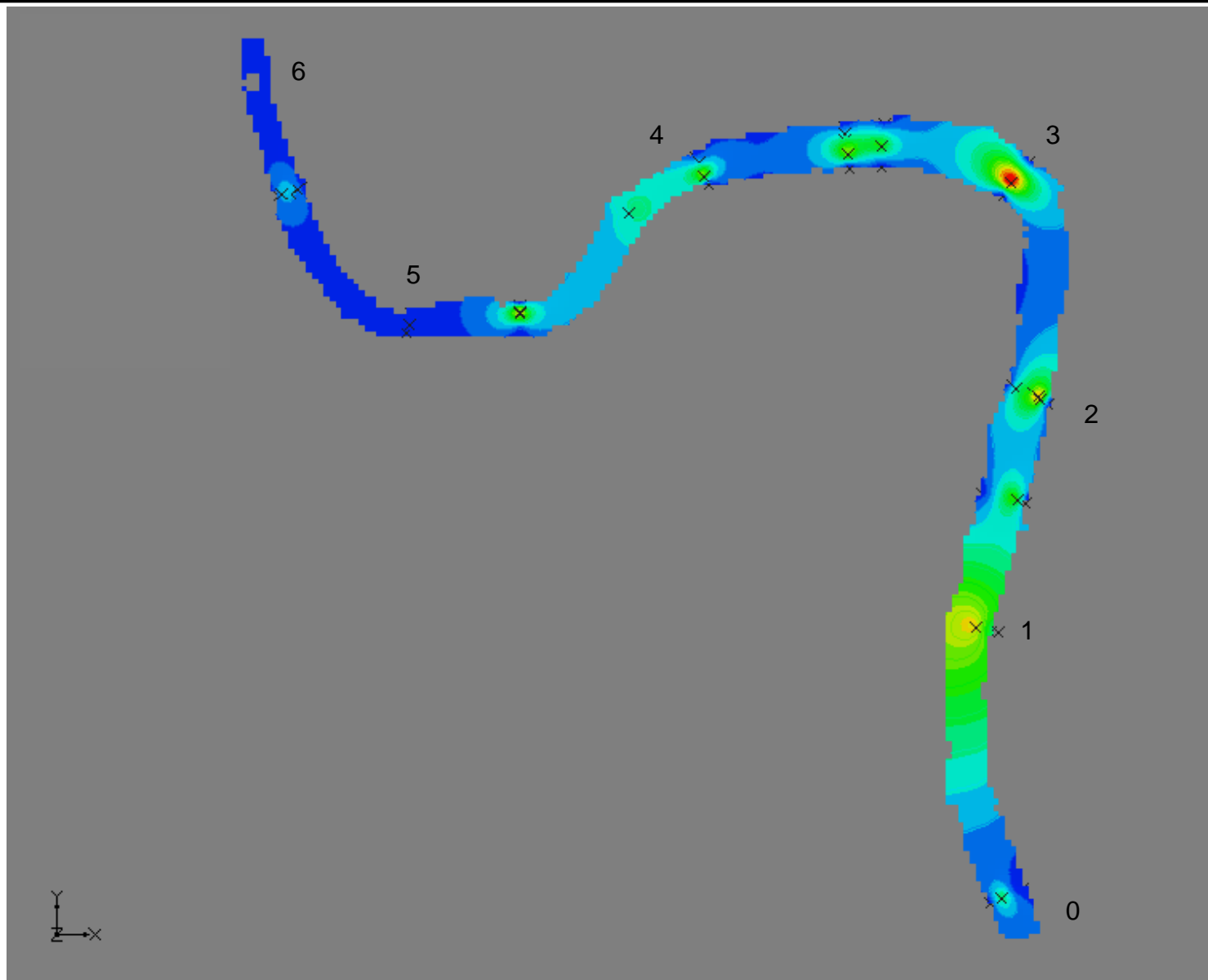
Location:
River Mile 0 to River Mile 6

Interpolated Thickness of Recent Fined Grained
Sediments (RM 0 to RM 6)

Lower Passaic River Restoration Project

Figure 5-1a

February 2006
Draft

Legend

Thickness of Silt (cm)

140
130
120
110
100
90
80
70
60
50
40
30
20
10
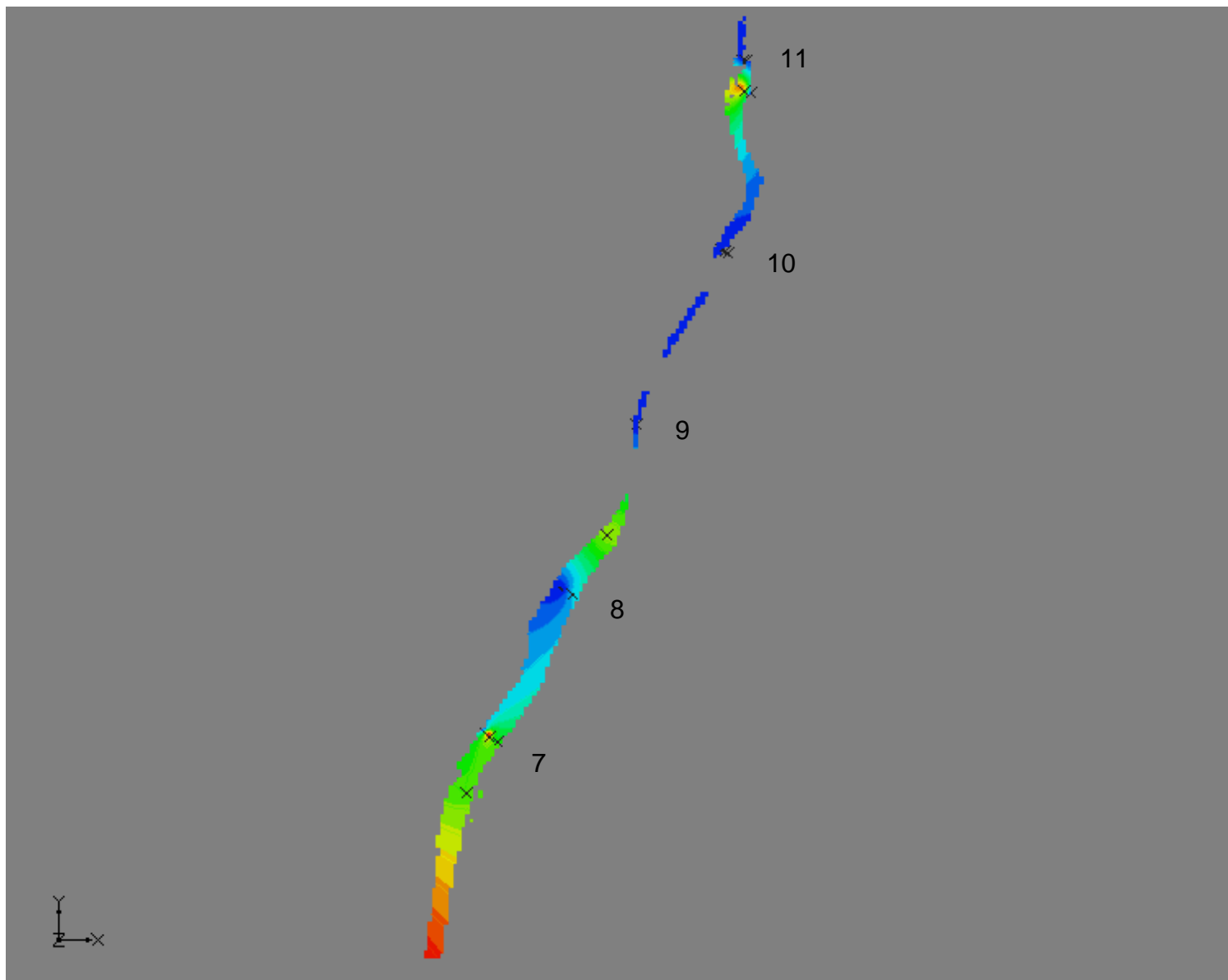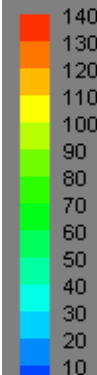
Location:
River Mile 6 to River Mile 11

Interpolated Thickness of Recent Fined Grained
Sediments (RM 6 to RM 11)

Lower Passaic River Restoration Project

Figure 5-1b

February 2006
Draft

Legend

Thickness of Silt (cm)

140
130
120
110
100
90
80
70
60
50
40
30
20
10
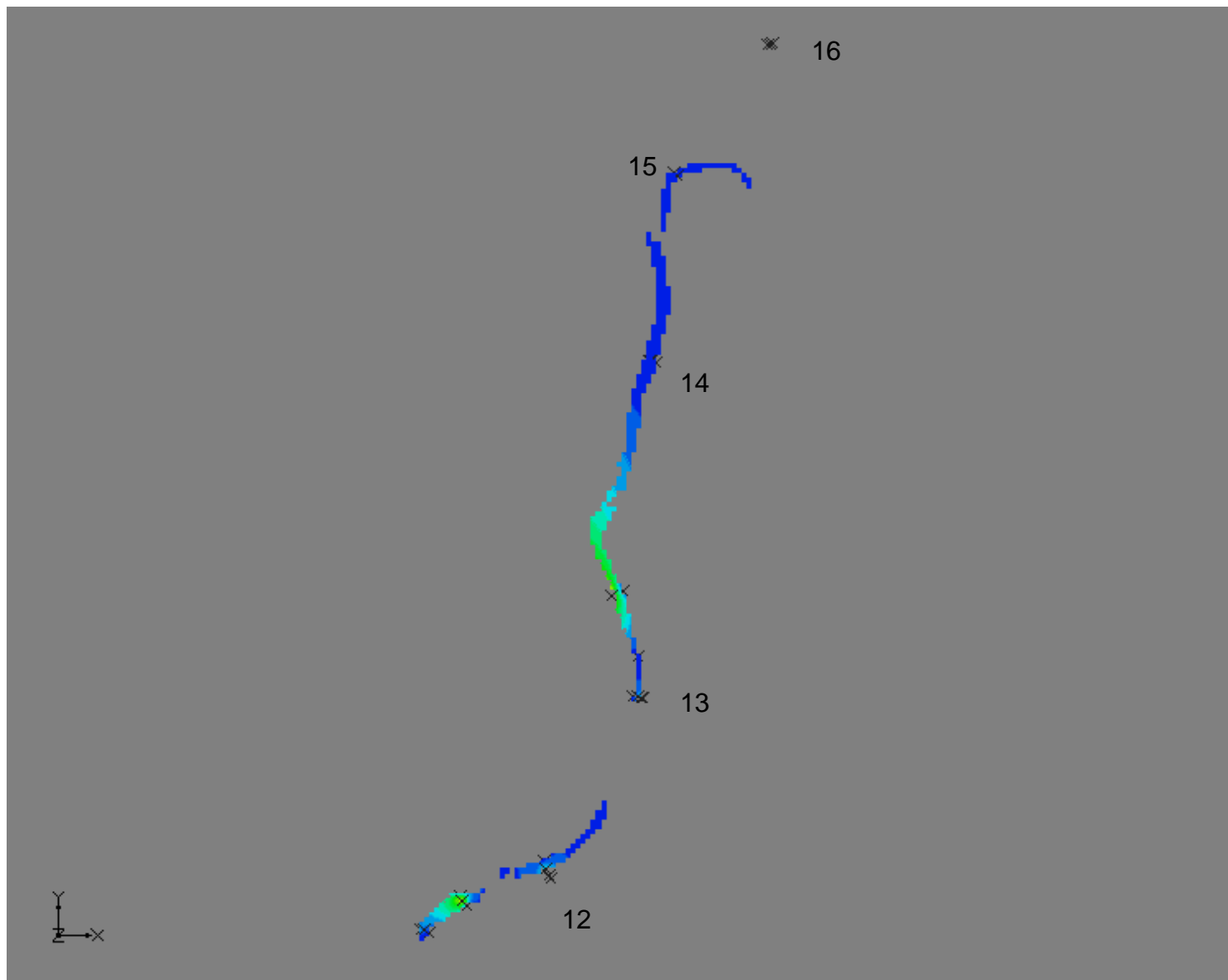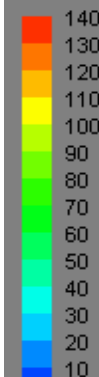
Location:
River Mile 11 to River Mile 16

Interpolated Thickness of Recent Fined Grained
Sediments (RM 11 to RM 16)

Lower Passaic River Restoration Project

Figure 5-1c

February 2006
Draft

Legend

Mass Per Unit Area (g/m^2)

■ (blue)	<0.01
■ (light blue)	0.01 - 0.032
■ (cyan)	0.032 - 0.1
■ (green)	0.1 - 0.32
■ (light green)	0.32 - 1.0
■ (yellow)	1.0 - 3.2
■ (orange)	3.2 - 10
■ (red)	10 - 3100 [a]

Core Type

Continuous

○ ≤ 10 ng/g at core bottom

◑ > 10 ng/g at core bottom, Bottom Conc < 50% Max Conc

● > 10 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated [b]

△ ≤ 10 ng/g at core bottom

◮ > 10 ng/g at core bottom, Bottom Conc < 50% Max Conc

▲ > 10 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)

△	○	0 - 5
△	○	5 - 10
△	○	10 - 15
△	○	15 - 20

Rejected Measurement(s) Present in Core [c]

*

River Mile Marker

✛ 1

Notes:
[a] MPA scale was combined since only 4 data present in this range.
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
[c] Rejected values were replaced with an interpolated value based on adjoining segments in the core.

500 250 0 500 Feet

N

Total DDT (Sum of 4,4'-DDT, 4,4'-DDD and 4,4'-DDE) Mass Per Unit Area - River Mile 1 to River Mile 2

Lower Passaic River Restoration Project

Figure 5-2
Page 1 of 6

February 2006
Draft

MALCOLM PIRNIE
INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

US Army Corps of Engineers®

Map Document: (P:\0285924\Mapping\Geochem_Evaluation\Thiessen_MPA\DDT MPA\DDT_Thiessen_RM1_2.mxd)

Legend

Mass Per Unit Area (g/m^2)

- <0.01
- 0.011 - 0.032
- 0.032 - 0.1
- 0.1 - 0.32
- 0.32 - 1.0
- 1.001 - 3.160
- 3.2 - 10
- 10 - 3100[a]

Core Type

Continuous

- ○ ≤ 10 ng/g at core bottom
- ◐ > 10 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ● > 10 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]

- △ ≤ 10 ng/g at core bottom
- ◭ > 10 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ > 10 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (ft)

- △ ○ 0 - 5
- △ ○ 5 - 10
- △ ○ 10 - 15
- △ ○ 15 - 20

Rejected Measurement(s) Present in Core[c]

∗

River Mile Marker

+ 1

Notes:
[a] MPA scale was combined since only 4 data present in this range.
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
[c] Rejected values were replaced with an interpolated value based on adjoining segments in the core.

Total DDT (Sum of 4,4'-DDT, 4,4'-DDD and 4,4'-DDE) Mass Per Unit Area - River Mile 2 to River Mile 3

Lower Passaic River Restoration Project

Figure 5-2
Page 2 of 6

February 2006
Draft

MALCOLM PIRNIE
INDEPENDENT ENVIRONMENTAL
ENGINEERS, SCIENTISTS
AND CONSULTANTS

Map Document: (P:\0285924\Mapping\Geochem_Evaluation\Thiessen_MPA\DDT_MPA\DDT_Thiessen_RM2_3.mxd)

Legend

Mass Per Unit Area (g/m²)

- <0.01
- 0.011 - 0.032
- 0.032 - 0.1
- 0.1 - 0.32
- 0.32 - 1.0
- 1.001 - 3.160
- 3.2 - 10
- 10 - 3100[a]

Core Type

Continuous
- ○ ≤ 10 ng/g at core bottom
- ◐ > 10 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ● > 10 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]
- △ ≤ 10 ng/g at core bottom
- ◮ > 10 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ > 10 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (ft)

- △ ○ 0 - 5
- △ ○ 5 - 10
- △ ○ 10 - 15
- △ ○ 15 - 20

Rejected Measurement(s) Present in Core[c]
- ✳

River Mile Marker
- ＋ 1

Notes:
[a] MPA scale was combined since only 4 data present in this range.
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
[c] Rejected values were replaced with an interpolated value based on adjoining segments in the core.

500 250 0 500 Feet

N

Total DDT (Sum of 4,4'-DDT, 4,4'-DDD and 4,4'-DDE) Mass Per Unit Area - River Mile 3 to River Mile 4

Lower Passaic River Restoration Project

Figure 5-2
Page 3 of 6

February 2006
Draft

MALCOLM PIRNIE
INDEPENDENT ENVIRONMENTAL
ENGINEERS, SCIENTISTS
AND CONSULTANTS

Map Document: (P:\0285924\Mapping\Geochem_Evaluation\Thiessen_MPA\DDT MPA\DDT_Thiessen_RM3_4.mxd)

Legend

Mass Per Unit Area (g/m^2)
- █ <0.01
- █ 0.011 - 0.032
- █ 0.032 - 0.1
- █ 0.1 - 0.32
- █ 0.32 - 1.0
- █ 1.001 - 3.160
- █ 3.2 - 10
- █ 10 - 3100[a]

Core Type

Continuous
- ○ ≤ 10 ng/g at core bottom
- ◐ > 10 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ● > 10 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]
- △ ≤ 10 ng/g at core bottom
- ◭ > 10 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ > 10 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (ft)
- △ ○ 0 - 5
- △ ○ 5 - 10
- △ ○ 10 - 15
- △ ○ 15 - 20

Rejected Measurement(s) Present in Core[c]
- ✳

River Mile Marker
- ✛ 1

Notes:
[a] MPA scale was combined since only 4 data present in this range.
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
[c] Rejected values were replaced with an interpolated value based on adjoining segments in the core.

Total DDT (Sum of 4,4'-DDT, 4,4'-DDD and 4,4'-DDE) Mass Per Unit Area - River Mile 4 to River Mile 5
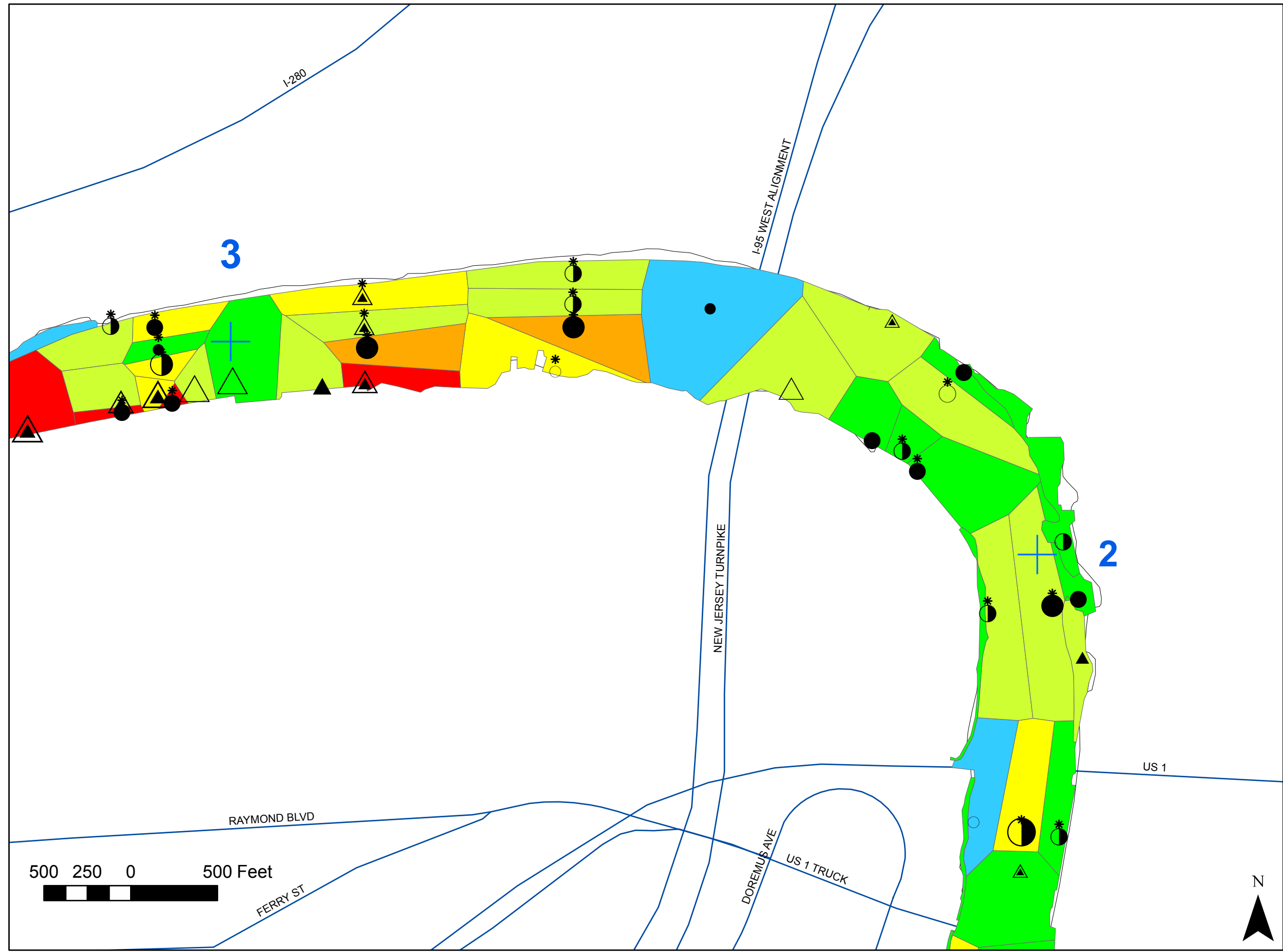
Lower Passaic River Restoration Project

Figure 5-2
Page 4 of 6

February 2006
Draft

MALCOLM PIRNIE

Map Document: (P:\0285924\Mapping\Geochem_Evaluation\Thiessen_MPA\DDT MPA\DDT_Thiessen_RM4_5.mxd)

Legend

Mass Per Unit Area (g/m^2)

- <0.01
- 0.01 - 0.032
- 0.032 - 0.1
- 0.1 - 0.32
- 0.32 - 1.0
- 1.0 - 3.2
- 3.2 - 10
- 10 - 3100 [a]

Core Type

Continuous

- ○ ≤ 10 ng/g at core bottom
- ◑ > 10 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ● > 10 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]

- △ ≤ 10 ng/g at core bottom
- ◮ > 10 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ > 10 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)

- △ ○ 0 - 5
- △ ○ 5 - 10
- △ ○ 10 - 15
- △ ○ 15 - 20

Rejected Measurement(s) Present in Core[c]

- ✳

River Mile Marker

- ✛ 1

Notes:
[a] MPA scale was combined since only 4 data present in this range.
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
[c] Rejected values were replaced with an interpolated value based on adjoining segments in the core.

500 250 0 500 Feet

N

Total DDT (Sum of 4,4'-DDT, 4,4'-DDD and 4,4'-DDE)
Mass Per Unit Area - River Mile 5 to River Mile 6

Lower Passaic River Restoration Project

Figure 5-2
Page 5 of 6

February 2006
Draft

MALCOLM PIRNIE
INDEPENDENT ENVIRONMENTAL
ENGINEERS, SCIENTISTS
AND CONSULTANTS

Legend

Mass Per Unit Area (g/m^2)

- **<0.01** (blue)
- **0.01 - 0.032** (light blue)
- **0.032 - 0.1** (cyan)
- **0.1 - 0.32** (green)
- **0.32 - 1.0** (light green)
- **1.0 - 3.2** (yellow)
- **3.2 - 10** (orange)
- **10 - 3100** [a] (red)

Core Type

Continuous

- ○ ≤ 10 ng/g at core bottom
- ◐ > 10 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ● > 10 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated [b]

- △ ≤ 10 ng/g at core bottom
- ◭ > 10 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ > 10 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)

△	○	0 - 5
△	○	5 - 10
△	○	10 - 15
△	○	15 - 20

Rejected Measurement(s) Present in Core [c]
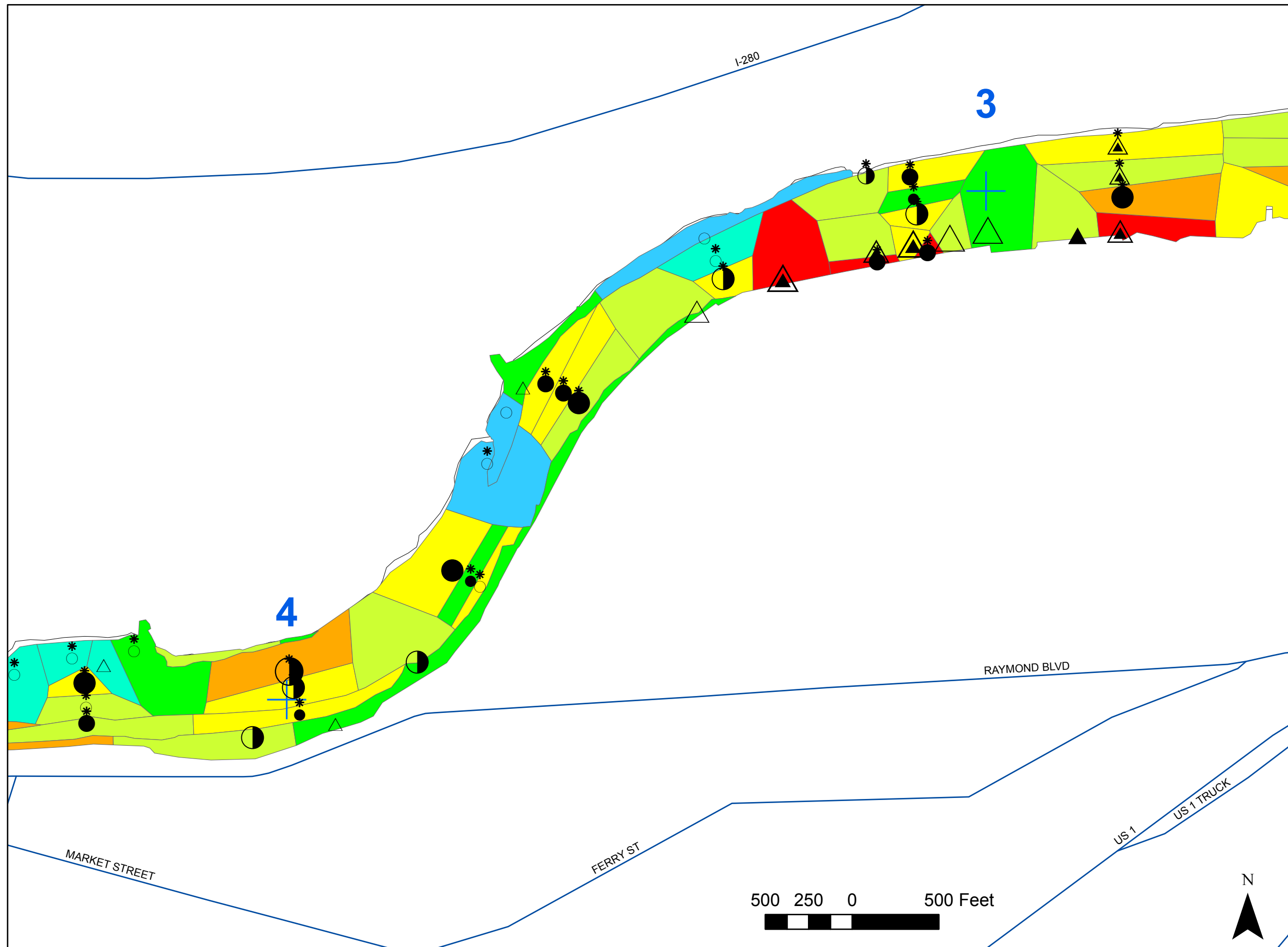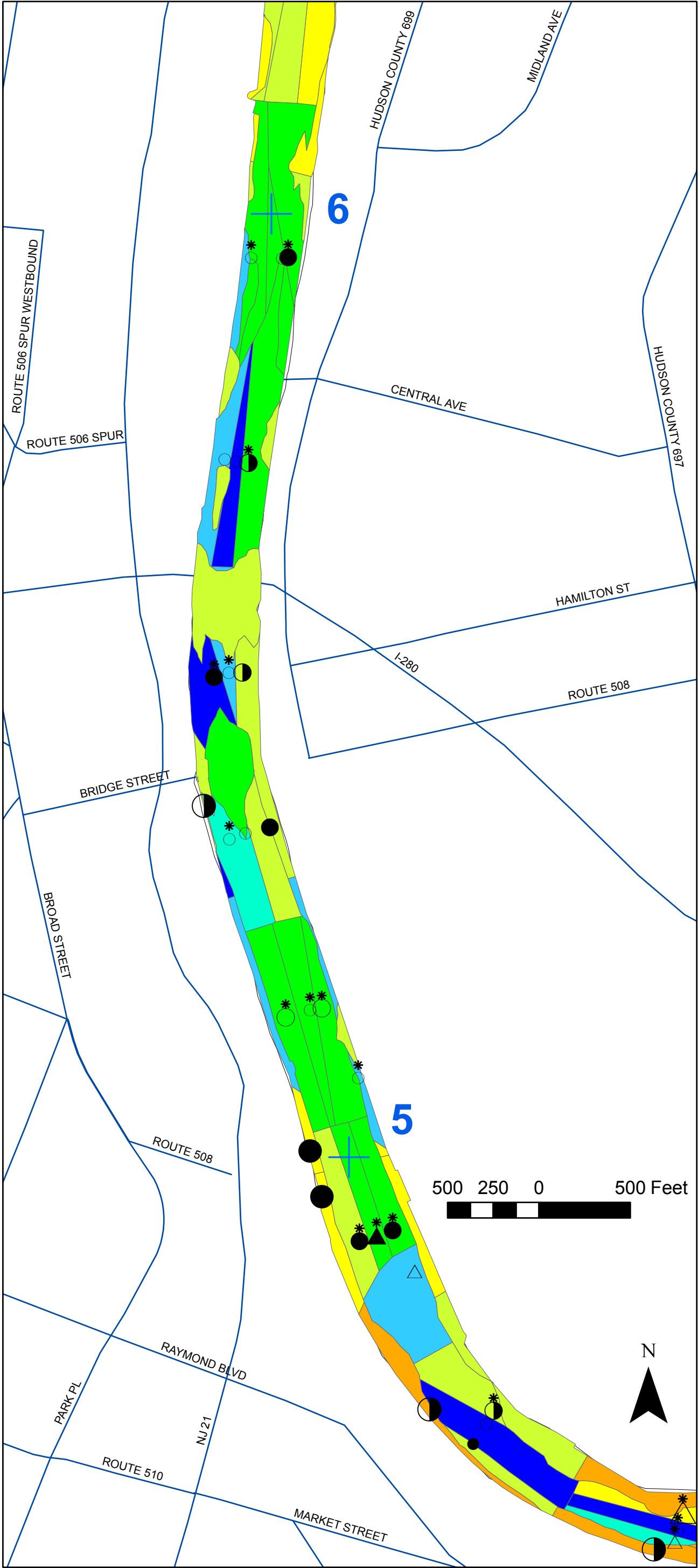
✳

River Mile Marker

✛ 1

Notes:
[a] MPA scale was combined since only 4 data present in this range.
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
[c] Rejected values were replaced with an interpolated value based on adjoining segments in the core.

500 250 0 500 Feet

N

Total DDT (Sum of 4,4'-DDT, 4,4'-DDD and 4,4'-DDE)
Mass Per Unit Area - River Mile 6 to River Mile 7

Lower Passaic River Restoration Project

Figure 5-2
Page 6 of 6

February 2006
Draft

MALCOLM PIRNIE
INDEPENDENT ENVIRONMENTAL
ENGINEERS, SCIENTISTS
AND CONSULTANTS

Legend

Mass Per Unit Area (mg/m^2)

- < 0.01
- 0.01 - 0.032
- 0.032 - 0.1
- 0.1 - 0.32
- 0.32 - 1.0
- 1.0 - 3.2
- 3.2 - 10
- 10 - 32
- 32 - 1300[a]

Core Type

Continuous

- ○ < 2 pg/g at core bottom
- ◑ ≥ 2 pg/g at core bottom, Bottom Conc < 50% Max Conc
- ● ≥ 2 pg/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]

- △ < 2 pg/g at core bottom
- ◬ ≥ 2 pg/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ ≥ 2 pg/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)

- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 20

River Mile Marker

- ╬ 1

Notes:
  There is no rejected measurement present for 2,3,7,8-TCDD.
[a] MPA scale was combined since only 9 data present in this range.
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.

I-95 WEST ALIGNMENT
NEW JERSEY TURNPIKE
RAYMOND BLVD
US 1 TRUCK
US 1
DOREMUS AVE

500 250 0   500 Feet

N

2,3,7,8-TCDD Mass Per Unit Area
River Mile 1 to River Mile 2
Lower Passaic River Restoration Project

Figure 5-3
Page 1 of 6
February 2006
Draft

US Army Corps of Engineers®

MALCOLM PIRNIE
INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

Legend

Mass Per Unit Area (mg/m^2)

- **< 0.01** (blue)
- **0.01 - 0.032** (light blue)
- **0.032 - 0.1** (cyan)
- **0.1 - 0.32** (green)
- **0.32 - 1.0** (light green)
- **1.0 - 3.2** (yellow)
- **3.2 - 10** (gold)
- **10 - 32** (orange)
- **32 - 1300**[a] (red)

Core Type

Continuous

- ○ < 2 pg/g at core bottom
- ◐ ≥ 2 pg/g at core bottom, Bottom Conc < 50% Max Conc
- ● ≥ 2 pg/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]

- △ < 2 pg/g at core bottom
- △ ≥ 2 pg/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ ≥ 2 pg/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)

- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 20

River Mile Marker

- + 1

Notes:
There is no rejected measurement present for 2,3,7,8-TCDD.
[a] MPA scale was combined since only 9 data present in this range.
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.

500 250 0 500 Feet

N

2,3,7,8-TCDD Mass Per Unit Area - River Mile 2 to River Mile 3

Lower Passaic River Restoration Project

Figure 5-3
Page 2 of 6

February 2006
Draft

MALCOLM PIRNIE
INDEPENDENT ENVIRONMENTAL
ENGINEERS, SCIENTISTS
AND CONSULTANTS

Map Document: (P:\0285924\Mapping\Geochem_Evaluation\Thiessen_MPA\TCDD MPA\TCDD_Thiessen_RM2_3.mxd)

Legend

Mass Per Unit Area (mg/m^2)

- ▮ < 0.01
- ▮ 0.01 - 0.032
- ▮ 0.032 - 0.1
- ▮ 0.1 - 0.32
- ▮ 0.32 - 1.0
- ▮ 1.0 - 3.2
- ▮ 3.2 - 10
- ▮ 10 - 32
- ▮ 32 - 1300[a]

Core Type

Continuous

- ○ < 2 pg/g at core bottom
- ◐ ≥ 2 pg/g at core bottom, Bottom Conc < 50% Max Conc
- ● ≥ 2 pg/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]

- △ < 2 pg/g at core bottom
- ◮ ≥ 2 pg/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ ≥ 2 pg/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)

- △ ○ 0 - 5
- △ ○ 5 - 10
- △ ○ 10 - 15
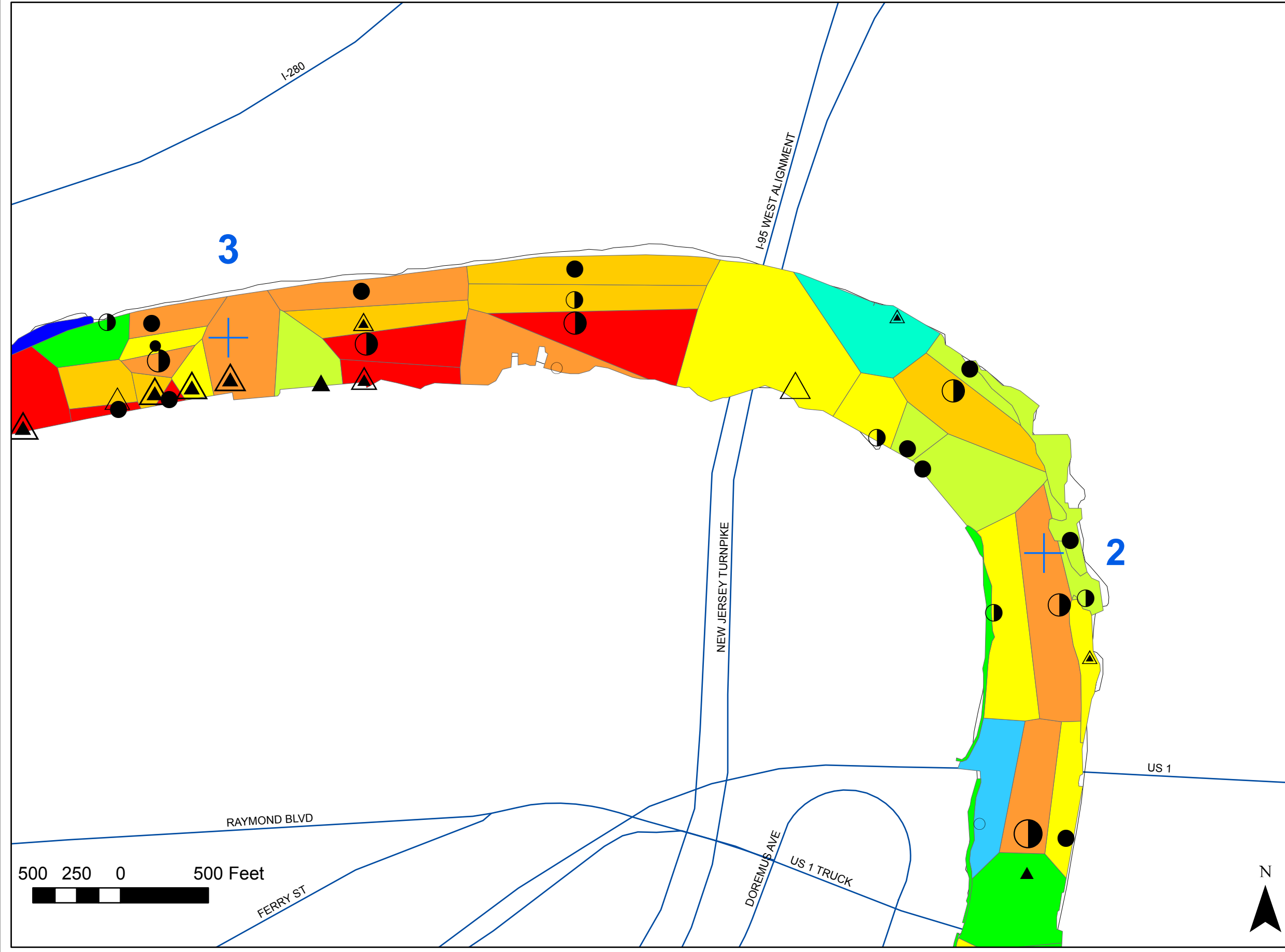- △ ○ 15 - 20

River Mile Marker

- + 1

Notes:
There is no rejected measurement present for 2,3,7,8-TCDD.
[a] MPA scale was combined since only 9 data present in this range.
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.

I-280

RAYMOND BLVD

MARKET STREET

FERRY ST

US 1 TRUCK

US 1

N

500 250 0 500 Feet

2,3,7,8-TCDD Mass Per Unit Area - River Mile 3 to River Mile 4

Lower Passaic River Restoration Project

US Army Corps of Engineers[®]

Figure 5-3
Page 3 of 6

February 2006
Draft

MALCOLM PIRNIE
INDEPENDENT ENVIRONMENTAL
ENGINEERS, SCIENTISTS
AND CONSULTANTS

Map Document: (P:\028592\Mapping\Geochem_Evaluation\Thiessen_MPA\TCDD_MPA\TCDD_Thiessen_RM3_4.mxd)

Legend

Mass Per Unit Area (mg/m²)
- ▮ < 0.01
- ▮ 0.01 - 0.032
- ▮ 0.032 - 0.1
- ▮ 0.1 - 0.32
- ▮ 0.32 - 1.0
- ▮ 1.0 - 3.2
- ▮ 3.2 - 10
- ▮ 10 - 32
- ▮ 32 - 1300[a]

Core Type

Continuous
- ○ < 2 pg/g at core bottom
- ◐ ≥ 2 pg/g at core bottom, Bottom Conc < 50% Max Conc
- ● ≥ 2 pg/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]
- △ < 2 pg/g at core bottom
- ◮ ≥ 2 pg/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ ≥ 2 pg/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)
- △ ○ 0 - 5
- △ ○ 5 - 10
- △ ○ 10 - 15
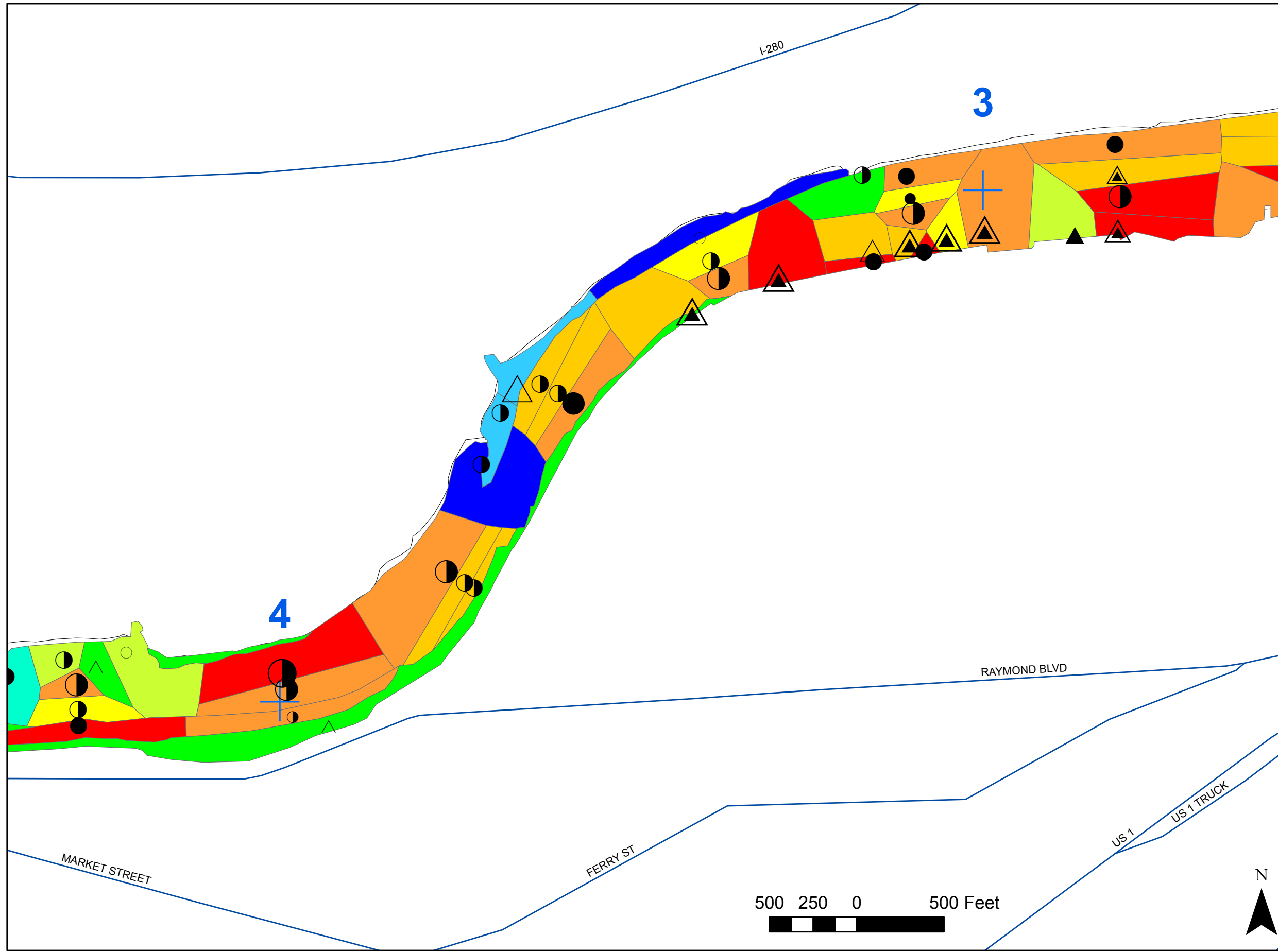- △ ○ 15 - 20

River Mile Marker
- + 1

Notes:
There is no rejected measurement present for 2,3,7,8-TCDD.
[a] MPA scale was combined since only 9 data present in this range.
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.

500 250 0 500 Feet

N

2,3,7,8-TCDD Mass Per Unit Area - River Mile 4 to River Mile 5

Lower Passaic River Restoration Project

Figure 5-3
Page 4 of 6

February 2006
Draft

MALCOLM PIRNIE
INDEPENDENT ENVIRONMENTAL
ENGINEERS, SCIENTISTS
AND CONSULTANTS

Map Document: (P:\0285924\Mapping\Geochem_Evaluation\Thiessen_MPA\TCDD MPA\TCDD_Thiessen_RM4_5.mxd)

Legend

Mass Per Unit Area (mg/m^2)

- < 0.01
- 0.01 - 0.032
- 0.032 - 0.1
- 0.1 - 0.32
- 0.32 - 1.0
- 1.0 - 3.2
- 3.2 - 10
- 10 - 32
- 32 - 1300[a]

Core Type

Continuous

- ◯ < 2 pg/g at core bottom
- ◑ ≥ 2 pg/g at core bottom, Bottom Conc < 50% Max Conc
- ● ≥ 2 pg/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]

- △ < 2 pg/g at core bottom
- ◮ ≥ 2 pg/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ ≥ 2 pg/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)

- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 20

River Mile Marker

- ✛ 1

Notes:

There is no rejected measurement present for 2,3,7,8-TCDD.

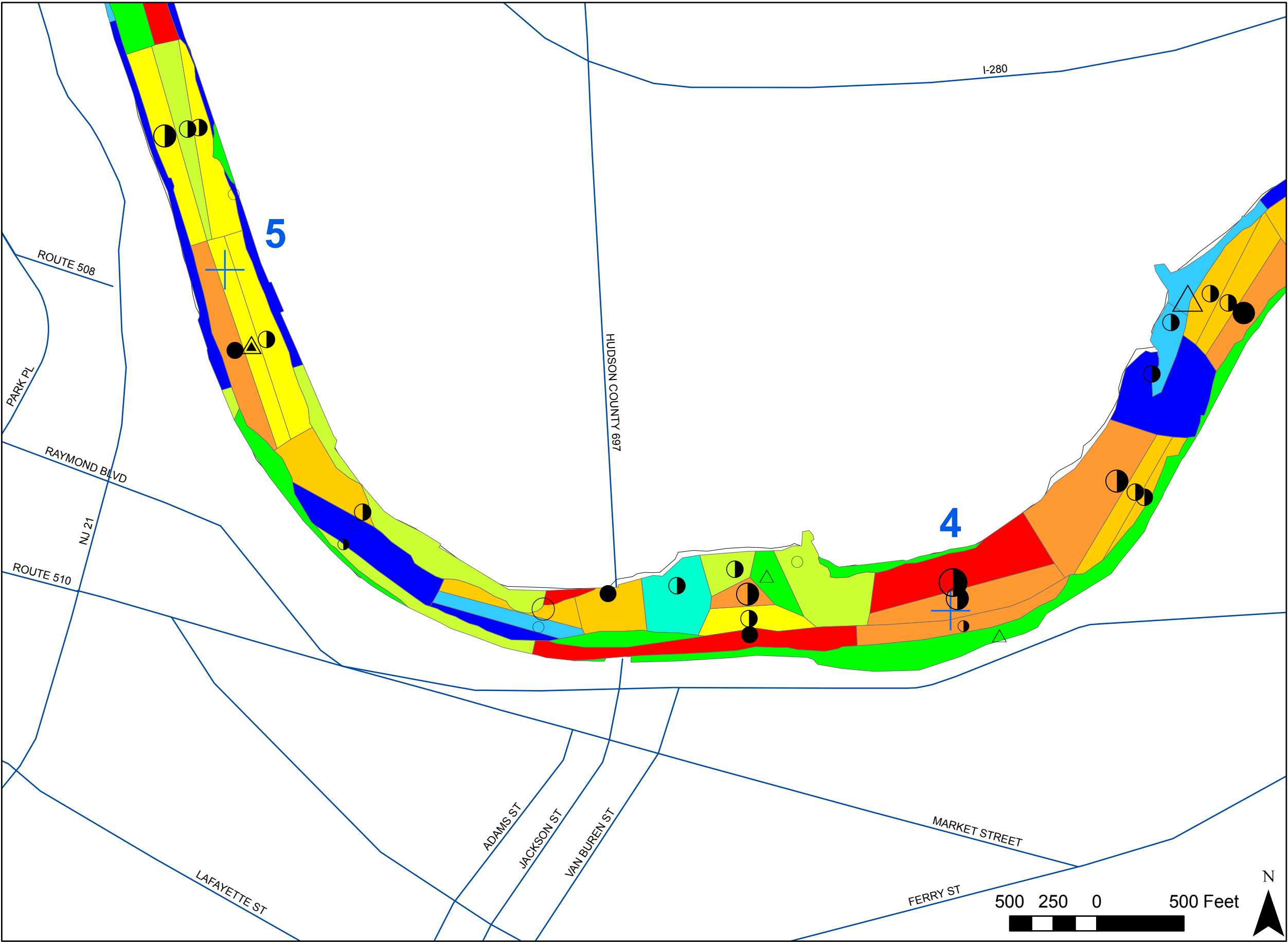[a] MPA scale was combined since only 9 data present in this range.

[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.

500 250 0 500 Feet

N

2,3,7,8-TCDD Mass Per Unit Area
River Mile 5 to River Mile 6

Lower Passaic River Restoration Project

Figure 5-3
Page 5 of 6
February 2006
Draft

Legend

Mass Per Unit Area (mg/m^2)

- █ < 0.01
- █ 0.01 - 0.032
- █ 0.032 - 0.1
- █ 0.1 - 0.32
- █ 0.32 - 1.0
- █ 1.0 - 3.2
- █ 3.2 - 10
- █ 10 - 32
- █ 32 - 1300[a]

Core Type

Continuous

- ○ < 2 pg/g at core bottom
- ◐ ≥ 2 pg/g at core bottom, Bottom Conc < 50% Max Conc
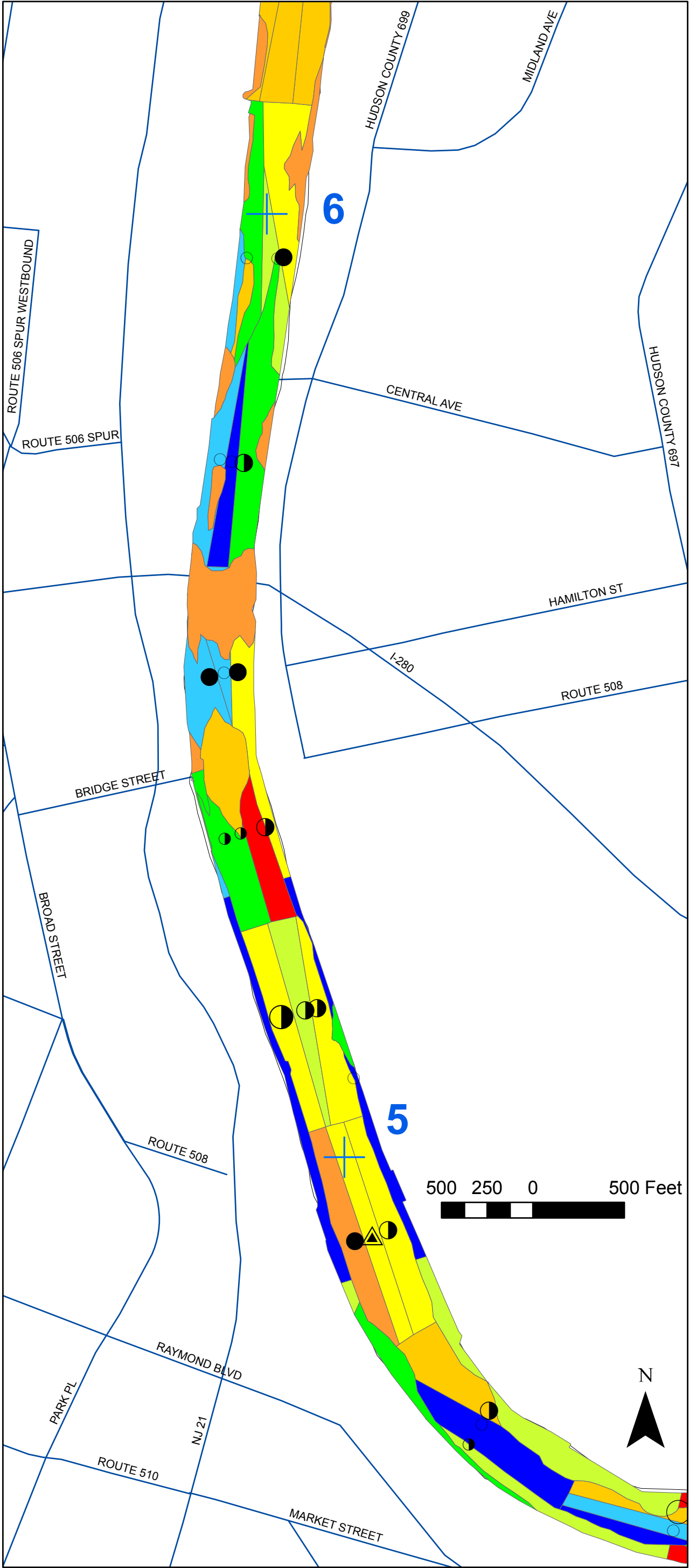- ● ≥ 2 pg/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]

- △ < 2 pg/g at core bottom
- ◭ ≥ 2 pg/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ ≥ 2 pg/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)

- △ ○ 0 - 5
- △ ○ 5 - 10
- △ ○ 10 - 15
- △ ○ 15 - 20

River Mile Marker

- ✛ 1

Notes:
There is no rejected measurement present for 2,3,7,8-TCDD.
[a] MPA scale was combined since only 9 data present in this range.
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
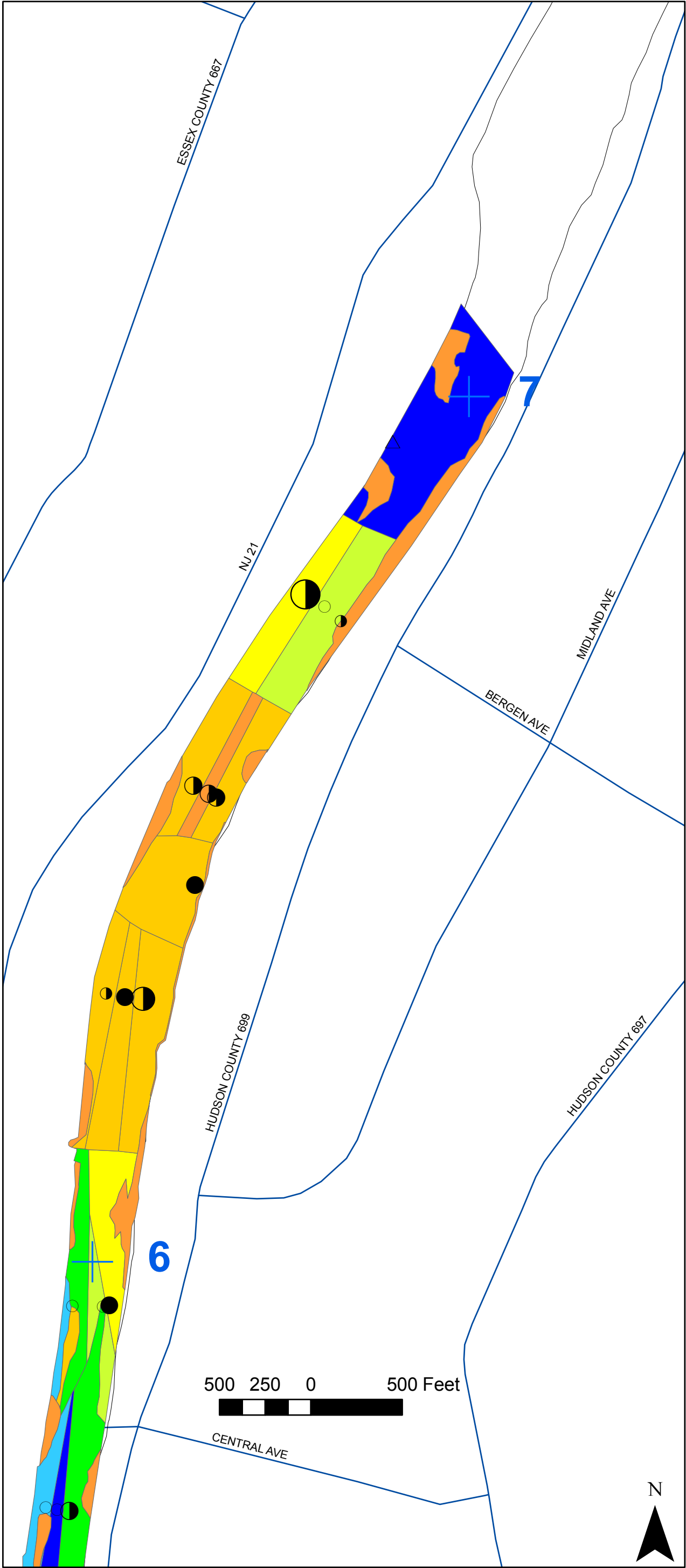
Map labels: ESSEX COUNTY 667, NJ 21, MIDLAND AVE, BERGEN AVE, HUDSON COUNTY 699, HUDSON COUNTY 697, CENTRAL AVE

Scale: 500 250 0 500 Feet

N

2,3,7,8-TCDD Mass Per Unit Area
River Mile 6 to River Mile 7
Lower Passaic River Restoration Project

Figure 5-3
Page 6 of 6
February 2006
Draft

MALCOLM PIRNIE
INDEPENDENT ENVIRONMENTAL
ENGINEERS, SCIENTISTS
AND CONSULTANTS

Map Document: (P:\0285924\Mapping\Geochem_Evaluation\Thiessen_MPA\TCDD MPA\TCDD_Thiessen_RM6_7.mxd)

US Army Corps of Engineers®

Legend

Mass Per Unit Area (g/m^2)

- < 0.32
- 0.32 - 1.0
- 1.0 - 3.2
- 3.2 - 10
- 10 - 36[a]

Core Type

Continuous

- ○ < 125 ng/g at core bottom
- ◐ ≥ 125 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ● ≥ 125 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]

- △ < 125 ng/g at core bottom
- ◮ ≥ 125 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ ≥ 125 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)

- △ ○ 0 - 5
- △ ○ 5 - 10
- △ ○ 10 - 15
- △ ○ 15 - 20

Rejected Measurement(s) Present in Core[c]

- *

River Mile Marker

- ╂ 1

Notes:
[a] MPA scale was combined since only 1 data point is higher than 32 g/m^2.
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
[c] Rejected measurement present in one or more segments for one or more analytes.
Rejected values were replaced with an interpolated value based on adjoining segments in the core.

Map labels: I-95 WEST ALIGNMENT, NEW JERSEY TURNPIKE, RAYMOND BLVD, US 1 TRUCK, US 1, DOREMUS AVE

500 250 0 500 Feet

N

Sum of Aroclors 1248, 1254 and 1260
Mass Per Unit Area - River Mile 1 to River Mile 2

Lower Passaic River Restoration Project

Figure 5-4
Page 1 of 6

February 2006
Draft

US Army Corps of Engineers®

MALCOLM PIRNIE

Legend

Mass Per Unit Area (g/m²)

Color	Value
Cyan	< 0.32
Green	0.32 - 1.0
Yellow	1.0 - 3.2
Orange	3.2 - 10
Red	10 - 36

Core Type

Continuous
- ◐ (open circle) < 125 ng/g at core bottom
- ◑ (half circle) ≥ 125 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ● (filled circle) ≥ 125 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[1]
- △ (open triangle) < 125 ng/g at core bottom
- ◮ (half triangle) ≥ 125 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ (filled triangle) ≥ 125 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (ft)

Triangle	Circle	Range
△	○	0 - 5
△	○	5 - 10
△	○	10 - 15
△	○	15 - 20

Rejected Measurement(s) Present in Core
✱

River Mile Marker
+ 1

Notes:
[a] MPA scale was combined since only 1 data point is higher than 32 g/m².
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
[c] Rejected measurement present in one or more segments for one or more analytes. Rejected values were replaced with an interpolated value based on adjoining segments in the core.

Sum of Aroclors 1248, 1254 and 1260 Mass Per Unit Area - River Mile 2 to River Mile 3
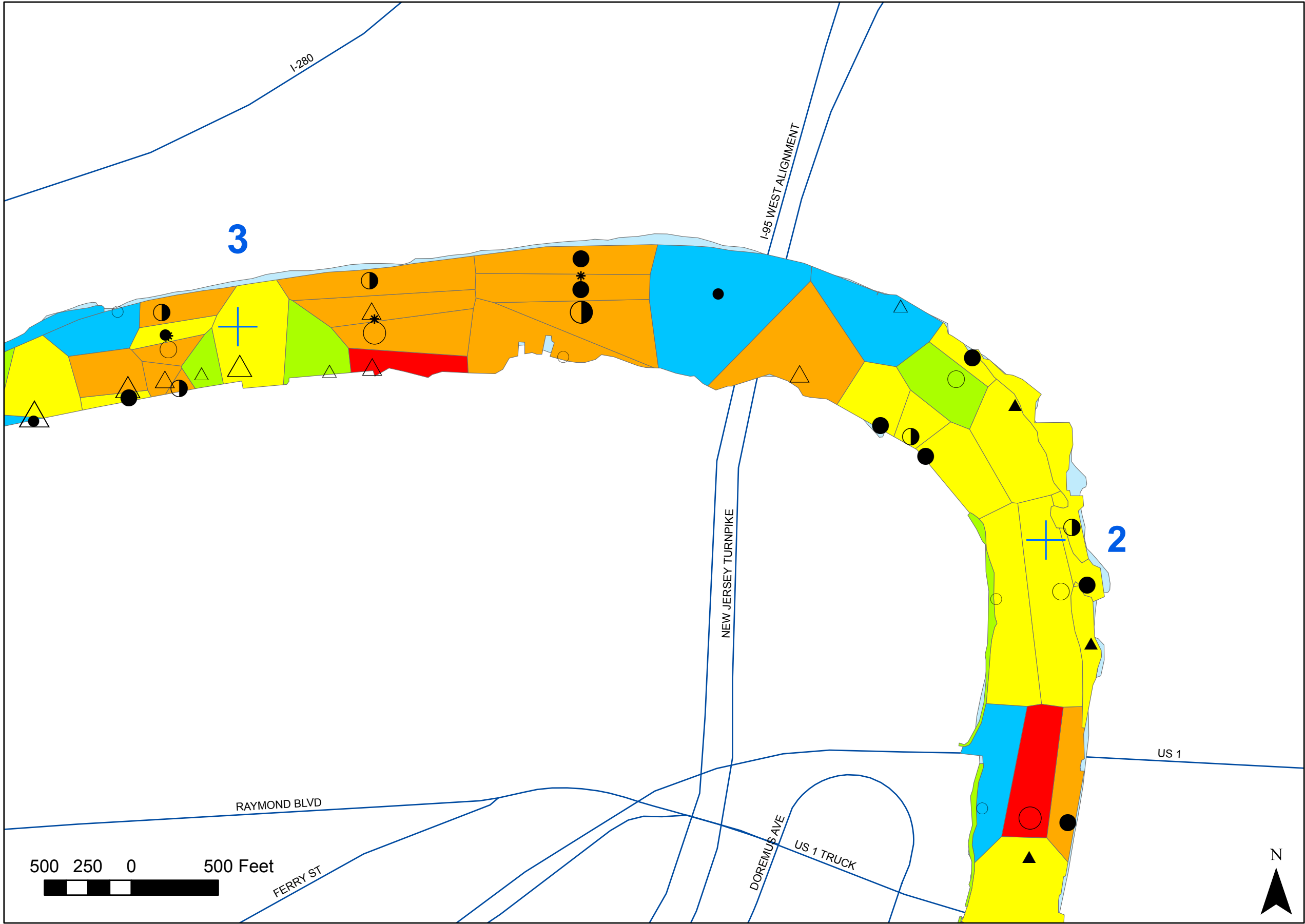
Lower Passaic River Restoration Project

Figure 5-4
Page 2 of 6

February 2006
Draft

Map Document: (P:\028592\Mapping\Geochem_Evaluation\Thiessen_MPA\PCB MPA\PCBSum_Thiessen_RM2_3.mxd)

Legend

Mass Per Unit Area (g/m^2)
- < 0.32
- 0.32 - 1.0
- 1.0 - 3.2
- 3.2 - 10
- 10 - 36

Core Type

Continuous
- ○ < 125 ng/g at core bottom
- ◐ ≥ 125 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ● ≥ 125 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[1]
- △ < 125 ng/g at core bottom
- ◭ ≥ 125 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ ≥ 125 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (ft)
- △ ○ 0 - 5
- △ ○ 5 - 10
- △ ○ 10 - 15
- △ ○ 15 - 20

Rejected Measurement(s) Present in Core
- ✳

River Mile Marker
- ✛ 1

Notes:
[a] MPA scale was combined since only 1 data point is higher than 32 g/m^2.
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
[c] Rejected measurement present in one or more segments for one or more analytes. Rejected values were replaced with an interpolated value based on adjoining segments in the core.
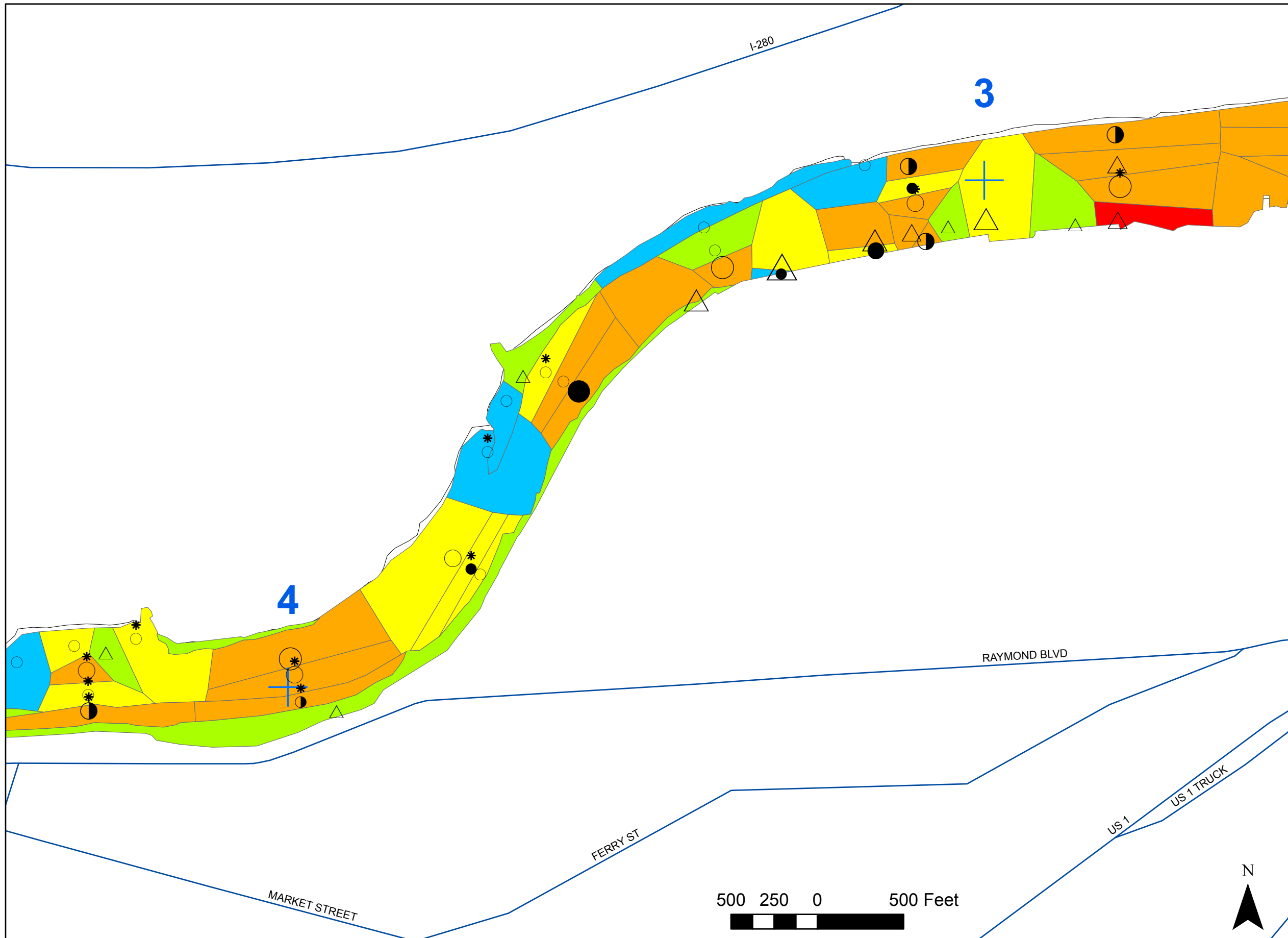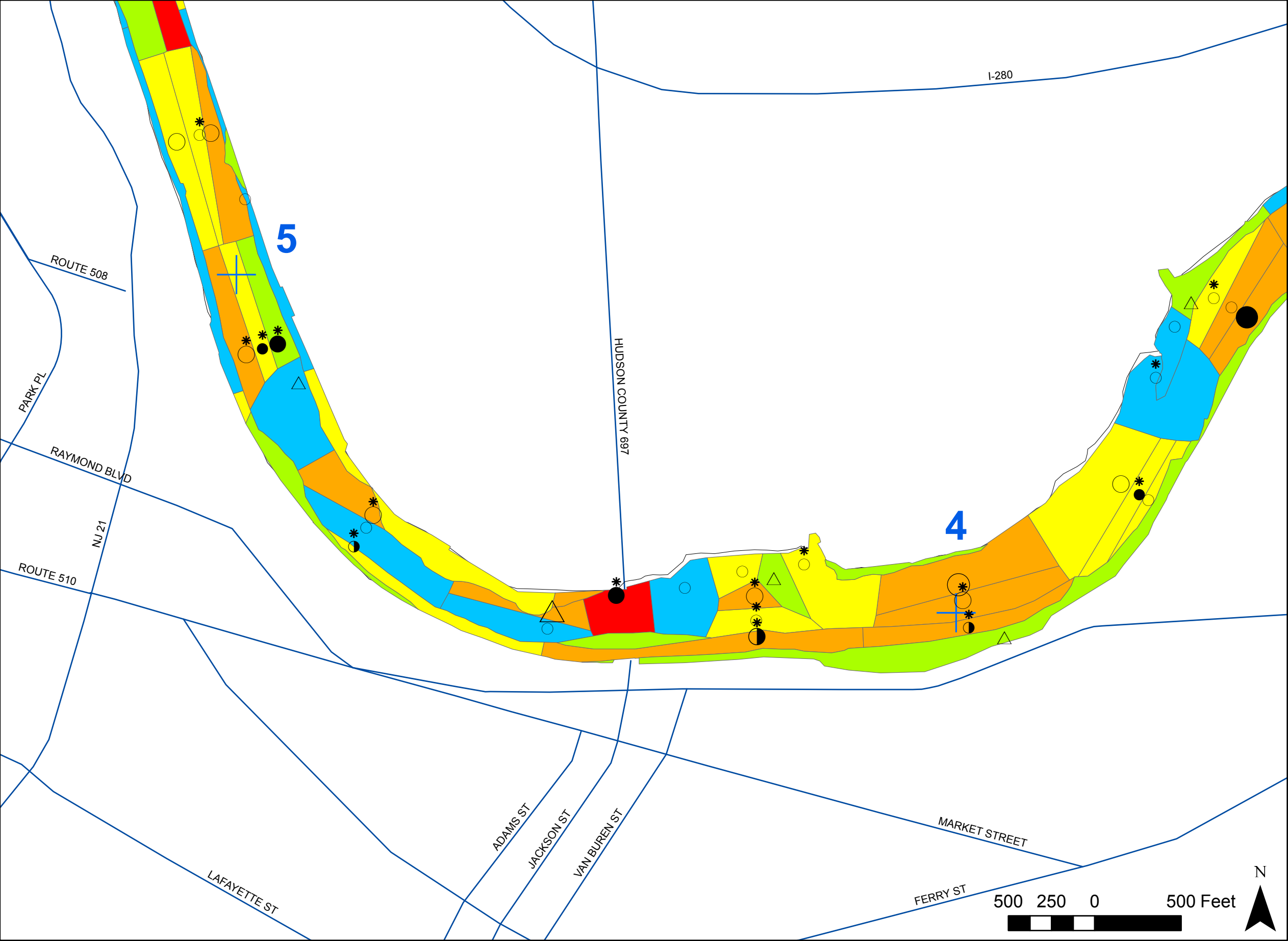
I-280

RAYMOND BLVD

FERRY ST

MARKET STREET

US 1

US 1 TRUCK

500 250 0 500 Feet

N

Sum of Aroclors 1248, 1254 and 1260 Mass Per Unit Area - River Mile 3 to River Mile 4

Lower Passaic River Restoration Project

Figure 5-4
Page 3 of 6
February 2006
Draft

MALCOLM PIRNIE
INDEPENDENT ENVIRONMENTAL
ENGINEERS, SCIENTISTS
AND CONSULTANTS

US Army Corps of Engineers

Map Document: (P:\0285924\Mapping\Geochem_Evaluation\Thiessen_MPA\PCB MPA\PCBSum_Thiessen_RM3_4.mxd)

Legend

Mass Per Unit Area (g/m²)

- 🟦 < 0.32
- 🟩 0.32- 1.0
- 🟨 1.0 - 3.2
- 🟧 3.2 - 10
- 🟥 10 - 36

Core Type

Continuous

- ○ < 125 ng/g at core bottom
- ◐ ≥ 125 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ● ≥ 125 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[1]

- △ < 125 ng/g at core bottom
- ◮ ≥ 125 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ ≥ 125 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (ft)

△	○	0 - 5
△	○	5 - 10
△	○	10 - 15
△	○	15 - 20

Rejected Measurement(s) Present in Core
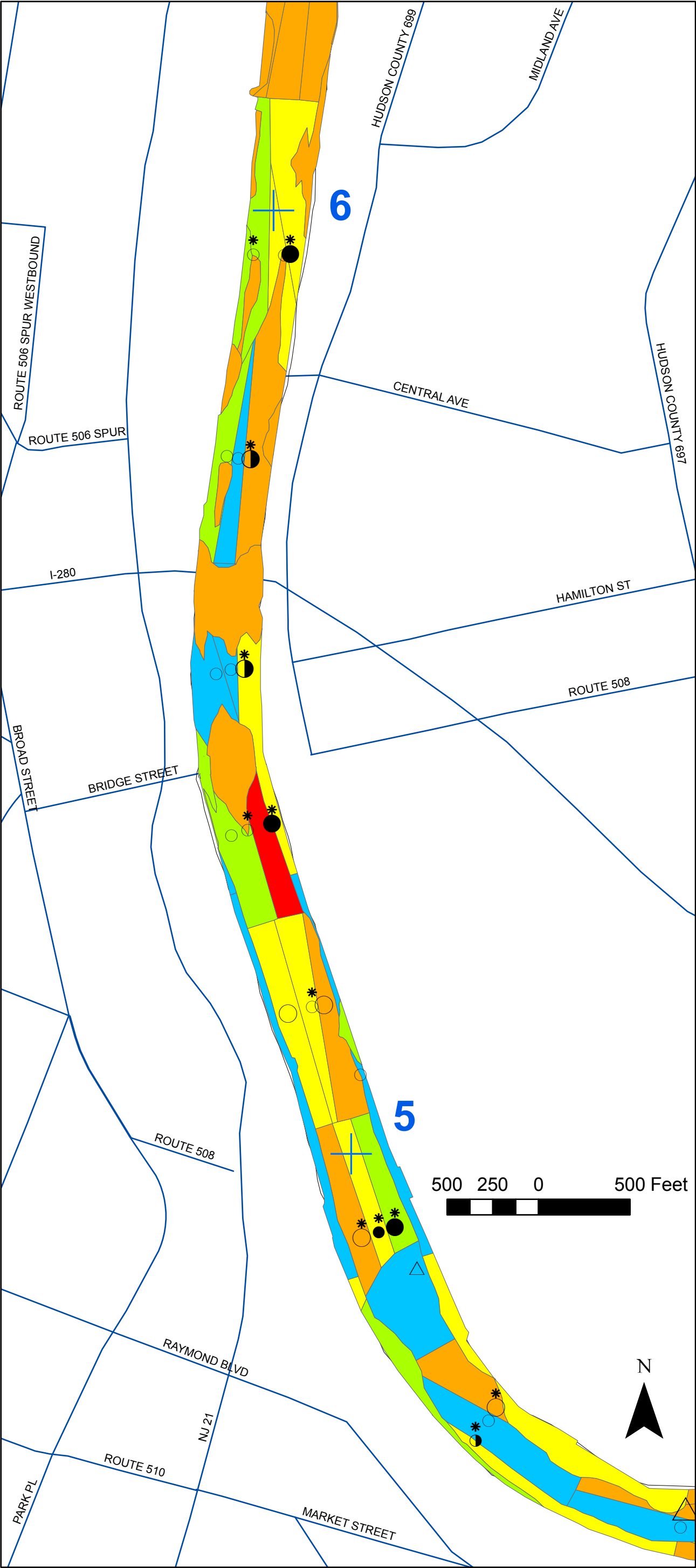
✱

River Mile Marker

+ 1

Notes:
[a] MPA scale was combined since only 1 data point is higher than 32 g/m².
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
[c] Rejected measurement present in one or more segments for one or more analytes. Rejected values were replaced with an interpolated value based on adjoining segments in the core.

Map Document: (P:\0285924\Mapping\Geochem_Evaluation\Thiessen_MPA\PCB MPA\PCBSum_Thiessen_RM4_5.mxd)

500 250 0 500 Feet

N

Sum of Aroclors 1248, 1254 and 1260 Mass Per Unit Area - River Mile 4 to River Mile 5

Lower Passaic River Restoration Project

Figure 5-4
Page 4 of 6

February 2006
Draft

MALCOLM PIRNIE

Legend

Mass Per Unit Area (g/m²)

- < 0.32
- 0.32 - 1.0
- 1.0 - 3.2
- 3.2 - 10
- 10 - 36[a]

Core Type

Continuous

- ○ < 125 ng/g at core bottom
- ◑ ≥ 125 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ● ≥ 125 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]

- △ < 125 ng/g at core bottom
- ◮ ≥ 125 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ ≥ 125 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)

△	○	0 - 5
△	○	5 - 10
△	○	10 - 15
△	○	15 - 20

Rejected Measurement(s) Present in Core[c]

- ✳

River Mile Marker

- ✛ 1

Notes:
[a] MPA scale was combined since only 1 data point is higher than 32 g/m².
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
[c] Rejected measurement present in one or more segments for one or more analytes. Rejected values were replaced with an interpolated value based on adjoining segments in the core.

Sum of Aroclors 1248, 1254 and 1260
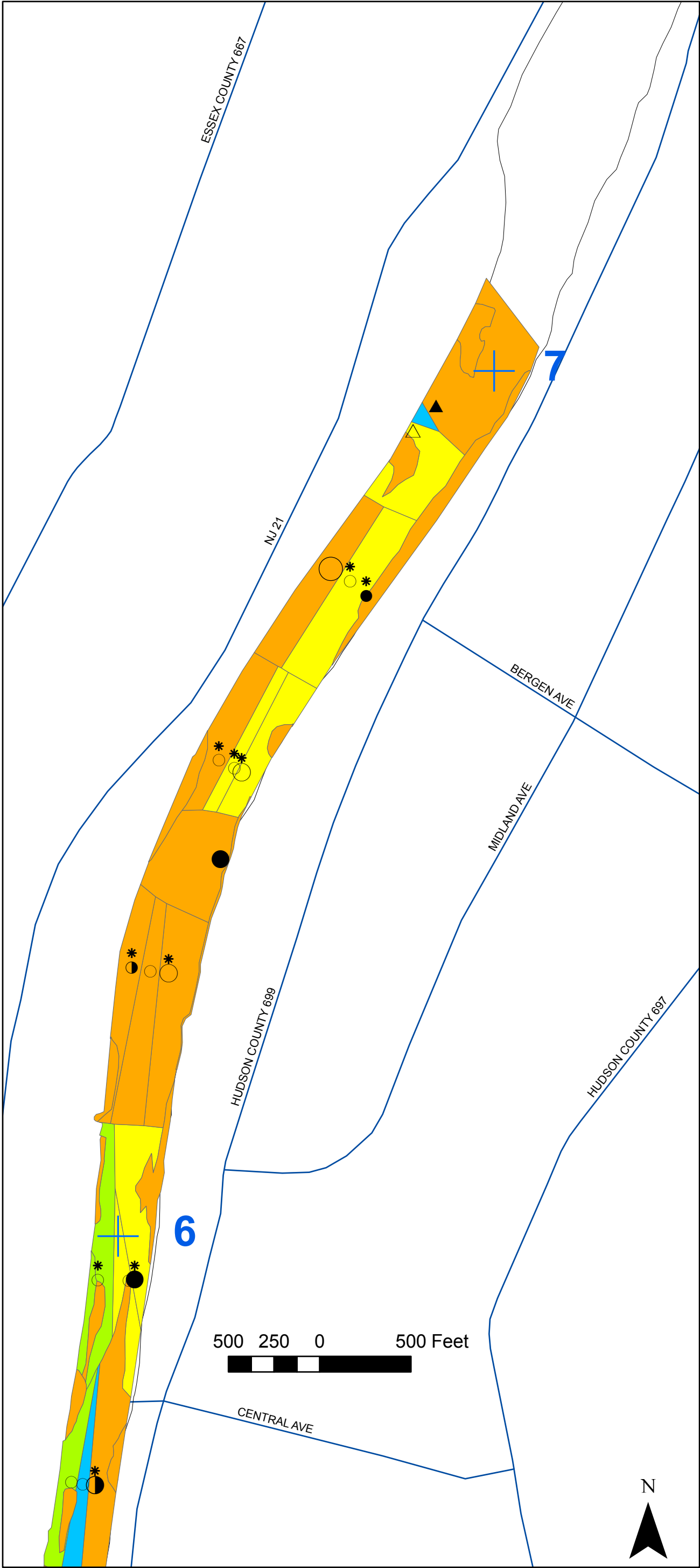Mass Per Unit Area - River Mile 5 to River Mile 6

Lower Passaic River Restoration Project

Figure 5-4
Page 5 of 6

February 2006
Draft

US Army Corps of Engineers®

MALCOLM PIRNIE

Legend

Mass Per Unit Area (g/m^2)

- < 0.32
- 0.32 - 1.0
- 1.0 - 3.2
- 3.2 - 10
- 10 - 36[a]

Core Type

Continuous

- ○ < 125 ng/g at core bottom
- ◑ ≥ 125 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ● ≥ 125 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]

- △ < 125 ng/g at core bottom
- ◭ ≥ 125 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ ≥ 125 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)

△	○	0 - 5
△	○	5 - 10
△	○	10 - 15
△	○	15 - 20

Rejected Measurement(s) Present in Core[c]

*

River Mile Marker

✛ 1

Notes:
[a] MPA scale was combined since only 1 data point is higher than 32 g/m^2.
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
[c] Rejected measurement present in one or more segments for one or more analytes. Rejected values were replaced with an interpolated value based on adjoining segments in the core.

500 250 0   500 Feet

N

Sum of Aroclors 1248, 1254 and 1260
Mass Per Unit Area - River Mile 6 to River Mile 7

Lower Passaic River Restoration Project

Figure 5-4
Page 6 of 6

February 2006
Draft

US Army Corps of Engineers

MALCOLM PIRNIE

Legend

Mass Per Unit Area[a] (g/m^2)

- < 1
- 0.32 - 1
- 1 - 3.2
- 3.2 - 10
- 10 - 32
- 32 - 64

Core Type

Continuous

- ○ < 200 ng/g at core bottom
- ◐ ≥ 200 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ● ≥ 200 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]

- △ < 200 ng/g at core bottom
- ◮ ≥ 200 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ ≥ 200 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)

△	○	0 - 5
△	○	5 - 10
△	○	10 - 15
△	○	15 - 20

Rejected Measurement(s) Present in Core[c]

✳

River Mile Marker

╋ 1

Notes:
[a] Mercury background for a 20-foot silt core is less than 0.24 g/m^2. Mercury background for a 6-foot silt core is less than 0.07 g/m^2.
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
[c] Rejected values were replaced with an interpolated value based on adjoining segments in the core.

Map labels: I-95 WEST ALIGNMENT, NEW JERSEY TURNPIKE, RAYMOND BLVD, US 1 TRUCK, US 1, DOREMUS AVE

500 250 0 500 Feet

N

Mercury Mass Per Unit Area - River Mile 1 to River Mile 2

Lower Passaic River Restoration Project

Figure 5-5
Page 1 of 6

February 2006
Draft

US Army Corps of Engineers, NOAA, Fish and Wildlife Service

MALCOLM PIRNIE

Legend

Mass Per Unit Area[a] (g/m²)

- < 1
- 0.32 - 1
- 1 - 3.2
- 3.2 - 10
- 10 - 32
- 32 - 64

Core Type

Continuous

- ○ < 200 ng/g at core bottom
- ◐ ≥ 200 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ● ≥ 200 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]

- △ < 200 ng/g at core bottom
- ◮ ≥ 200 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ ≥ 200 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)

- △ ○ 0 - 5
- △ ○ 5 - 10
- △ ○ 10 - 15
- △ ○ 15 - 20

Rejected Measurement(s) Present in Core[c]

∗

River Mile Marker

+ 1

Notes:
[a] Mercury background for a 20-foot silt core is less than 0.24 g/m².
Mercury background for a 6-foot silt core is less than 0.07 g/m².
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
[c] Rejected values were replaced with an interpolated value based on adjoining segments in the core.
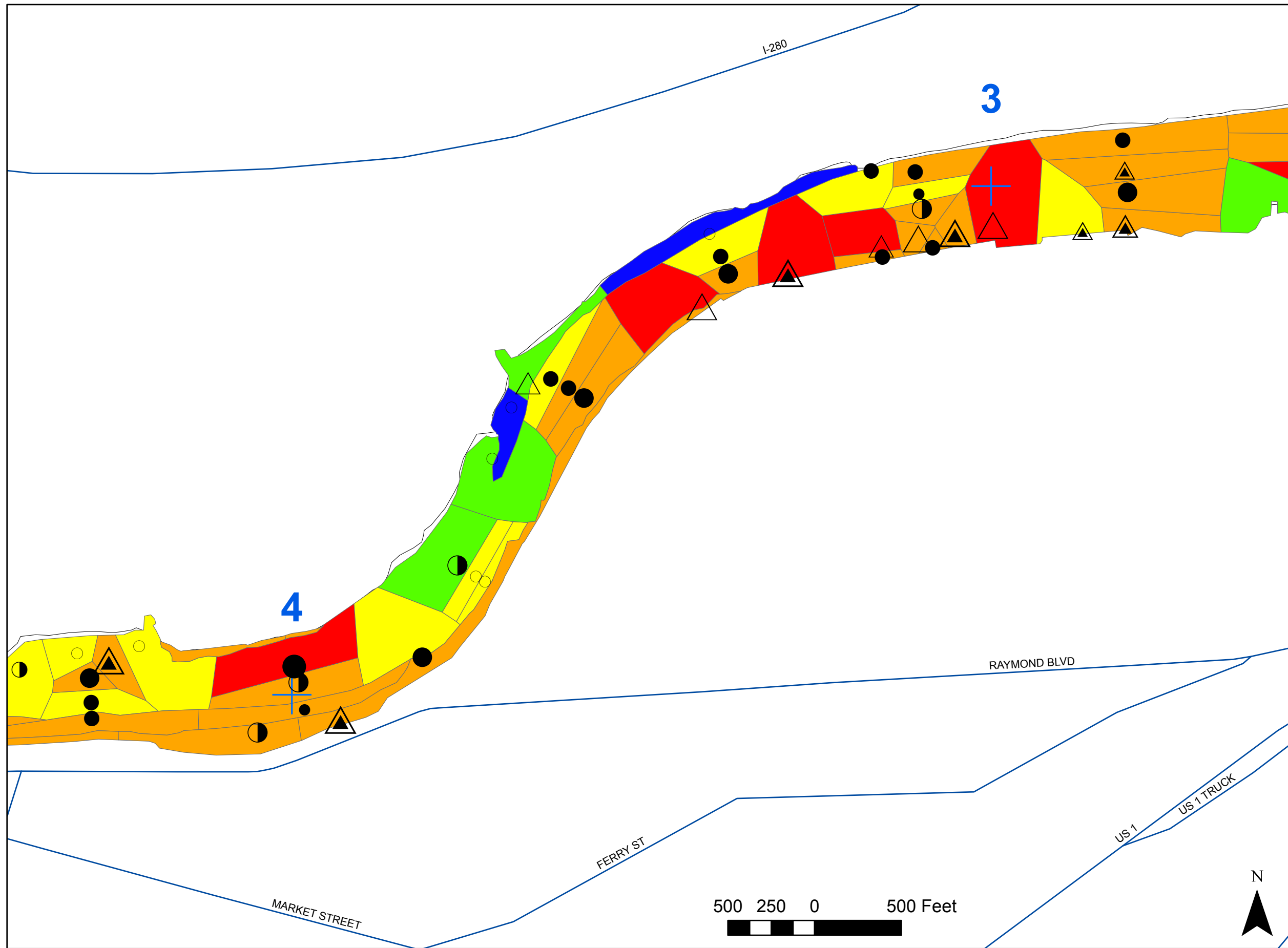
500 250 0   500 Feet

Mercury Mass Per Unit Area - River Mile 2 to River Mile 3

Lower Passaic River Restoration Project

Figure 5-5
Page 2 of 6

February 2006
Draft

MALCOLM PIRNIE
INDEPENDENT ENVIRONMENTAL
ENGINEERS, SCIENTISTS
AND CONSULTANTS

Map Document: (P:\0285924\Mapping\Geochem_Evaluation\Thiessen_MPA\Hg_Thiessen_MPA\Hg_Mercury_MPA\Hg_Thiessen_RM2_3.mxd)

Legend

Mass Per Unit Area[a] (g/m²)
- ■ < 1
- ■ 0.32 - 1
- ■ 1 - 3.2
- ■ 3.2 - 10
- ■ 10 - 32
- ■ 32 - 64

Core Type

Continuous
- ○ < 200 ng/g at core bottom
- ◑ ≥ 200 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ● ≥ 200 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]
- △ < 200 ng/g at core bottom
- ◮ ≥ 200 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ ≥ 200 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)
- △ ○   0 - 5
- △ ○   5 - 10
- △ ○   10 - 15
- △ ○   15 - 20

Rejected Measurement(s) Present in Core[c]
- ✳

River Mile Marker
- ✛ 1

Notes:
[a] Mercury background for a 20-foot silt core is less than 0.24 g/m². Mercury background for a 6-foot silt core is less than 0.07 g/m².
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
[c] Rejected values were replaced with an interpolated value based on adjoining segments in the core.

500 250 0   500 Feet

N

Mercury Mass Per Unit Area - River Mile 3 to River Mile 4

Lower Passaic River Restoration Project

Figure 5-5
Page 3 of 6
February 2006
Draft

MALCOLM PIRNIE

US Army Corps of Engineers

Map Document: (P:\0285924\Mapping\Geochem_Evaluation\Thiessen_MPA\Mercury MPA\Hg_Thiessen_RM3_4.mxd)

Figure 5-5
Page 4 of 6
February 2006
Draft

Mercury Mass Per Unit Area - River Mile 4 to River Mile 5

Lower Passaic River Restoration Project

Legend

Mass Per Unit Area^a (g/m^2)
- < 1
- 0.32 - 1
- 1 - 3.2
- 3.2 - 10
- 10 - 32
- 32 - 64

Core Type

Continuous
- ○ < 200 ng/g at core bottom
- ◐ ≥ 200 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ● ≥ 200 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated^b
- △ < 200 ng/g at core bottom
- ◭ ≥ 200 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ ≥ 200 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)
- △ ○ 0 - 5
- △ ○ 5 - 10
- △ ○ 10 - 15
- △ ○ 15 - 20

Rejected Measurement(s) Present in Core^c
- ✳

River Mile Marker
- + 1

Notes:
^{a} Mercury background for a 20-foot silt core is less than 0.24 g/m^2. Mercury background for a 6-foot silt core is less than 0.07 g/m^2.
^{b} Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
^{c} Rejected values were replaced with an interpolated value based on adjoining segments in the core.

500 250 0 500 Feet

N

Map Document: (P:\0285924\Mapping\Geochem_Evaluation\Thiessen_MPA\Hg_Thiessen_MPA\Hg_Thiessen_RM4_5.mxd)

Legend

Mass Per Unit Area[a] (g/m^2)

- ■ < 1
- ■ 0.32 - 1
- ■ 1 - 3.2
- ■ 3.2 - 10
- ■ 10 - 32
- ■ 32 - 64

Core Type

Continuous

- ○ < 200 ng/g at core bottom
- ◐ ≥ 200 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ● ≥ 200 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]

- △ < 200 ng/g at core bottom
- ◮ ≥ 200 ng/g at core bottom, Bottom Conc < 50% Max Conc
- ▲ ≥ 200 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)

△	○	0 - 5
△	○	5 - 10
△	○	10 - 15
△	○	15 - 20

Rejected Measurement(s) Present in Core[c]

✱

River Mile Marker

✛ 1

Notes:
[a] Mercury background for a 20-foot silt core is less than 0.24 g/m^2. Mercury background for a 6-foot silt core is less than 0.07 g/m^2.
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
[c] Rejected values were replaced with an interpolated value based on adjoining segments in the core.

Mercury Mass Per Unit Area - River Mile 5 to River Mile 6

Lower Passaic River Restoration Project

Figure 5-5
Page 5 of 6

February 2006
Draft

500 250 0 500 Feet

Legend

Mass Per Unit Area[a] (g/m^2)

- ■ < 1
- ■ 0.32 - 1
- ■ 1 - 3.2
- ■ 3.2 - 10
- ■ 10 - 32
- ■ 32 - 64

Core Type

Continuous

○ < 200 ng/g at core bottom

◐ ≥ 200 ng/g at core bottom, Bottom Conc < 50% Max Conc

● ≥ 200 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Interpolated[b]

△ < 200 ng/g at core bottom

◮ ≥ 200 ng/g at core bottom, Bottom Conc < 50% Max Conc

▲ ≥ 200 ng/g at core bottom, Bottom Conc ≥ 50% Max Conc

Depth (feet)

△	○	0 - 5
△	○	5 - 10
△	○	10 - 15
△	○	15 - 20

Rejected Measurement(s) Present in Core[c]

✳

River Mile Marker

✛ 1

Notes:
[a] Mercury background for a 20-foot silt core is less than 0.24 g/m^2. Mercury background for a 6-foot silt core is less than 0.07 g/m^2.
[b] Unlike a continuous core, an interpolated core was not sampled continuously throughout its length. Contaminant concentrations between measured intervals were linearly interpolated.
[c] Rejected values were replaced with an interpolated value based on adjoining segments in the core.

Mercury Mass Per Unit Area - River Mile 6 to River Mile 7

Lower Passaic River Restoration Project

Figure 5-5
Page 6 of 6

February 2006
Draft

MALCOLM PIRNIE
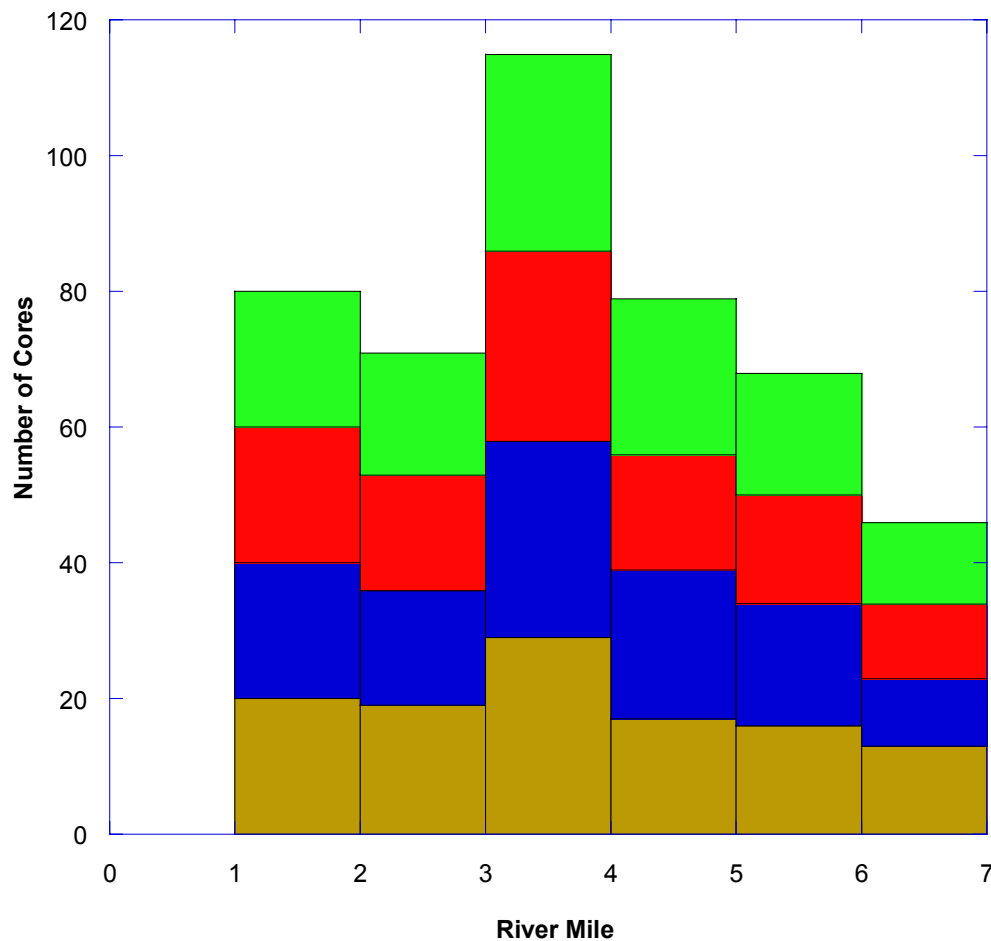
Legend

- Total DDT
- 2,3,7,8-TCDD
- Mercury
- Total PCB

Location
River Mile 1 to River Mile 7

Notes

Each coring location can generate up to four mass per unit area (MPA) values, one for each contaminant.

Weighted Curve Sediment Inventory versus River Mile

Figure 5-7
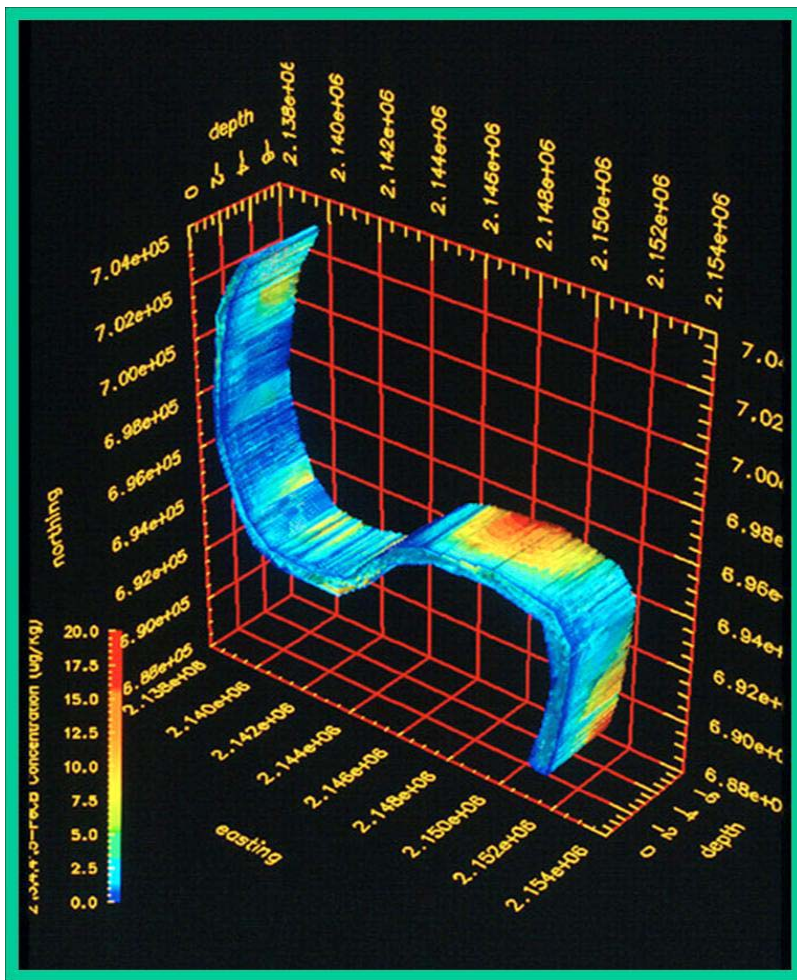
Lower Passaic River Restoration Project

February 2006
Draft

Figure 5-8

Mass Per Unit Area Correlation Matrix

Lower Passaic River Restoration Project

February 2006
Draft

3-Dimensional Distribution taken from Ma et al. (1998)

MPA Map for 2,3,7,8-TCDD for RM 1 through 7 (Figure 5-3)

Mass Per Unit Area (mg/m^2)

- < 0.01
- 0.01 - 0.032
- 0.032 - 0.1
- 0.1 - 0.32
- 0.32 - 1.0
- 1.0 - 3.2
- 3.2 - 10
- 10 - 32
- 32 - 100
- 100 - 1300

Comparison of 2,3,7,8-TCDD Spatial Extent

Figure 5-9

February 2006
Draft

Lower Passaic River Restoration Project

Appendix A:

**Supporting Documentation for
Sediment Mass Per Unit Area Calculations**

Table A-1
Inventory of Total DDT for RMs 1 to 7 Using 1991, 1993 and 1995 Data

Side Scan Sonar Sediment Texture	Count	Total DDT Mass (kg)	Percentage	Area (acres)	Percentage	Mean MPA (g/m^2)	Cores/Acre	Volume of Sediment (cy)[1]	Mass of Sediment (kg)[1]	Volume-Weighted Average Concentrations (mg/kg)	Average Depth (ft)
Rock and Coarse Gravel + Gravel and Sand	6	150	2.3%	29	7%	1.30	0.21	330,000	404,000,000	0.37	7.2
Sand	1	4	0.1%	3	1%	0.31	0.31	12,800	13,700,000	0.29	2.5
Silt and Sand	18	150	2.3%	42	11%	0.89	0.43	342,000	279,000,000	0.54	5.1
Silt	95	6,100	95%	308	81%	4.89	0.31	3,845,000	2,150,000,000	2.84	7.7
Total	120	6,400	100%	382	100%	4.14	0.31	4,530,000	2,800,000,000	2.29	7.4

Concentrations at the Core Bottom	Count	Total DDT Mass (kg)	Percentage	Area (acres)	Percentage	Mean MPA (g/m^2)	Cores/Acre	Volume of Sediment (cy)[1]	Mass of Sediment (kg)[1]	Volume-Weighted Average Concentrations (mg/kg)	Average Depth (ft)
< 10 ng/g	41	190	3.0%	129	34%	0.36	0.32	1,180,000	684,000,000	0.28	5.7
≥ 10 ng/g, ratio bottom to peak <0.5	36	2,300	35.9%	118	31%	4.81	0.30	1,697,000	1,170,000,000	1.97	8.9
≥ 10 ng/g, ratio bottom to peak ≥ 0.5	43	3,950	61.7%	135	35%	7.24	0.32	1,650,000	990,000,000	3.99	7.6
Total	120	6,400	100.0%	382	100%	4.14	0.31	4,530,000	2,800,000,000	2.29	7.4

Concentrations at the Core Bottom	Extrapolated Total DDT Mass (kg)	Percentage	Extrapolated Volume (cy)	Extrapolated Depth (ft)
< 10 ng/g	190	2%	1,180,000	5.7
≥ 10 ng/g, ratio bottom to peak <0.5	2,875	26%	2,120,000	11.1
≥ 10 ng/g, ratio bottom to peak ≥ 0.5	7,900	72%	3,300,000	15.2
Total	10,965	100%	6,600,000	10.7

Note:

[1] Numbers are rounded to 3 significant digits.

Table A-2
Inventory of 2,3,7,8-TCDD for RMs 1 to 7 Using 1991, 1993 and 1995 Data

Side Scan Sonar Sediment Texture	Count	2,3,7,8-TCDD Mass (g)	Percentage	Area (acres)	Percentage	Mean MPA (mg/m^2)	Cores/Acre	Volume of Sediment (cy)	Mass of Sediment (kg)	Volume-Weighted Average Concentrations (ug/kg)	Average Depth (ft)
Rock and Coarse Gravel + Gravel and Sand	2	1,400	7.1%	29	7%	12.10	0.07	161,000	197,000,000	7.1	3.5
Sand	1	92	0.5%	3	1%	7.11	0.31	21,000	22,000,000	4.2	4.1
Silt and Sand	15	880	4.5%	42	11%	5.20	0.36	338,000	275,000,000	3.2	5.0
Silt	91	17,200	88%	308	81%	13.78	0.30	4,370,000	2,440,000,000	7.0	8.8
Total	109	19,600	100%	382	100%	12.68	0.29	4,900,000	2,900,000,000	6.8	8.0

Concentrations at the Core Bottom	Count	2,3,7,8-TCDD Mass (g)	Percentage	Area (acres)	Percentage	Mean MPA (mg/m^2)	Cores/Acre	Volume of Sediment (cy)	Mass of Sediment (kg)	Volume-Weighted Average Concentrations (ug/kg)	Average Depth (ft)
< 2 pg/g	23	700	3.6%	96	25%	1.81	0.24	1,050,000	668,000,000	1.0	6.8
≥ 2 pg/g, ratio bottom to peak <0.5	59	13,500	68.9%	200	52%	16.68	0.29	2,970,000	1,755,000,000	7.7	9.2
≥ 2 pg/g, ratio bottom to peak ≥ 0.5	27	5,400	27.6%	86	23%	15.49	0.31	870,000	510,000,000	10.6	6.3
Total	109	19,600	100%	382	100%	12.68	0.29	4,900,000	2,900,000,000	6.8	8.0

Concentrations at the Core Bottom	Extrapolated 2,3,7,8-TCDD Mass (kg)	Percentage	Extrapolated Volume (cy)	Extrapolated Depth (ft)
< 2 pg/g	700	2%	1,100,000	7.1
≥ 2 pg/g, ratio bottom to peak <0.5	16,900	58%	3,700,000	11.5
≥ 2 pg/g, ratio bottom to peak ≥ 0.5	11,000	38%	1,740,000	12.5
Total	29,000	100%	6,500,000	10.5

Table A-3
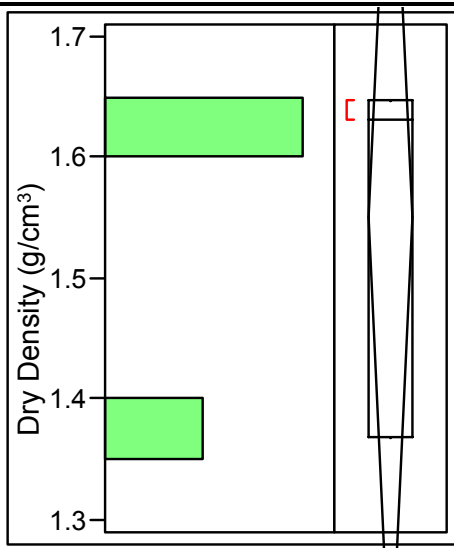**Inventory of Mercury for RMs 1 to 7 Using 1991, 1993 and 1995 Data**

Side Scan Sonar Sediment Texture	Count	Mercury Mass (kg)	Percentage	Area (acres)	Percentage	Mean MPA (mg/m²)	Cores/Acre	Volume of Sediment (cy)	Mass of Sediment (kg)	Volume-Weighted Average Concentrations (mg/kg)	Average Depth (ft)
Rock and Coarse Gravel + Gravel and Sand	6	2,700	11%	29	7%	23	0.21	513,000	628,000,000	4.3	11
Sand	1	134	0.6%	3	1%	10	0.31	13,000	13,700,000	9.8	2.5
Silt and Sand	17	1,210	5%	42	11%	7	0.41	320,000	261,000,000	4.6	4.7
Silt	92	19,700	83%	308	81%	16	0.30	4,430,000	2,470,000,000	8.0	8.9
Total	116	23,700	100%	382	100%	15	0.30	5,300,000	3,400,000,000	7.0	8.6

Concentrations at the Core Bottom	Count	Mercury Mass (kg)	Percentage	Area (acres)	Percentage	Mean MPA (mg/m²)	Cores/Acre	Volume of Sediment (cy)	Mass of Sediment (kg)	Volume-Weighted Average Concentrations (mg/kg)	Average Depth (ft)
< 200 ng/g	32	6,320	26.7%	98	26%	16	0.32	1,310,000	760,000,000	8.3	8.2
≥ 200 ng/g, ratio bottom to peak <0.5	28	6,000	25.3%	104	27%	14	0.27	1,660,000	1,109,000,000	5.4	9.9
≥ 200 ng/g, ratio bottom to peak ≥ 0.5	56	11,400	48.1%	179	47%	16	0.31	2,310,000	1,507,000,000	7.6	8.0
Total	116	23,700	100%	382	100%	15	0.30	5,300,000	3,400,000,000	7.0	8.6

Concentrations at the Core Bottom	Extrapolated Mercury Mass (kg)	Percentage	Extrapolated Volume (cy)	Extrapolated Depth (ft)
< 200 ng/g	6,320	17%	1,300,000	8.2
≥ 200 ng/g, ratio bottom to peak <0.5	7,500	20%	2,100,000	12.5
≥ 200 ng/g, ratio bottom to peak ≥ 0.5	23,000	62%	4,620,000	16.0
Total	37,000	100%	8,000,000	13.0

Table A-4
Inventory of Total PCB RMs 1 to 7 Using1991, 1993 and 1995 Data

Side Scan Sonar Sediment Texture	Count	TPCB Mass (kg)	Percentage	Area (acres)	Percentage	Mean MPA (mg/m^2)	Cores/Acre	Volume of Sediment (cy)	Mass of Sediment (kg)	Volume-Weighted Average Concentrations (mg/kg)	Average Depth (ft)
Rock and Coarse Gravel + Gravel and Sand	2	500	8%	29	7%	4.3	0.07	104,000	127,000,000	3.9	2.3
Sand	1	67	1.1%	3	1%	5.2	0.31	13,000	13,700,000	4.9	2.5
Silt and Sand	15	430	7%	42	11%	2.5	0.36	218,000	178,000,000	2.4	3.2
Silt	92	5,000	83%	308	81%	4.0	0.30	3,200,000	1,790,000,000	2.8	6.4
Total	110	6,000	100%	382	100%	3.9	0.29	3,500,000	2,100,000,000	2.9	5.7

Concentrations at the Core Bottom	Count	TPCB Mass (kg)	Percentage	Area (acres)	Percentage	Mean MPA (mg/m^2)	Cores/Acre	Volume of Sediment (cy)	Mass of Sediment (kg)	Volume-Weighted Average Concentrations (mg/kg)	Average Depth (ft)
< 125 ng/g	70	2,900	48.3%	227	59%	3	0.31	2,120,000	1,216,000,000	2.4	5.8
≥ 125 ng/g, ratio bottom to peak <0.5	14	990	16.5%	45	12%	5	0.31	440,000	295,000,000	3.4	6.0
≥ 125 ng/g, ratio bottom to peak ≥ 0.5	30	2,150	35.8%	110	29%	5	0.27	980,000	595,000,000	3.6	5.5
Total	114	6,000	100%	382	100%	4	0.30	3,500,000	2,100,000,000	2.9	5.7

Concentrations at the Core Bottom	Extrapolated TPCB Mass (kg)	Percentage	Extrapolated Volume (cy)	Extrapolated Depth (ft)
< 125 ng/g	2,900	36%	2,100,000	5.7
≥ 125 ng/g, ratio bottom to peak <0.5	1,200	15%	600,000	8.2
≥ 125 ng/g, ratio bottom to peak ≥ 0.5	4,000	50%	1,960,000	11
Total	8,000	100%	4,700,000	7.6

Table A-5
Study Name, Organization Name, Study ID used for MPA Calculations

Analyte	Survey_ID	Survey_Name	Study_ID	Study_Name	Org_ID	Organization_Name
Total DDT	701	UNK	533	PASSAIC 1993 Core Sediment Investigation - 01 (March)	6	USEPA
	702	UNK	534	PASSAIC 1993 Core Sediment Investigation - 02 (July)	6	USEPA
	706	UNK	538	PASSAIC 1995 RI Sampling Program	6	USEPA
	708	UNK	540	PASSAIC 1995 USACE Minish Park Investigation	6	USEPA
	699	UNK	531	PASSAIC 1991 Core Sediment Investigation	6	USEPA
2,3,7,8-TCDD	701	UNK	533	PASSAIC 1993 Core Sediment Investigation - 01 (March)	6	USEPA
	702	UNK	534	PASSAIC 1993 Core Sediment Investigation - 02 (July)	6	USEPA
	706	UNK	538	PASSAIC 1995 RI Sampling Program	6	USEPA
	699	UNK	531	PASSAIC 1991 Core Sediment Investigation	6	USEPA
Mercury	702	UNK	534	PASSAIC 1993 Core Sediment Investigation - 02 (July)	6	USEPA
	706	UNK	538	PASSAIC 1995 RI Sampling Program	6	USEPA
	708	UNK	540	PASSAIC 1995 USACE Minish Park Investigation	6	USEPA
	699	UNK	531	PASSAIC 1991 Core Sediment Investigation	6	USEPA
Total PCB	701	UNK	533	PASSAIC 1993 Core Sediment Investigation - 01 (March)	6	USEPA
	702	UNK	534	PASSAIC 1993 Core Sediment Investigation - 02 (July)	6	USEPA
	706	UNK	538	PASSAIC 1995 RI Sampling Program	6	USEPA
	699	UNK	531	PASSAIC 1991 Core Sediment Investigation	6	USEPA
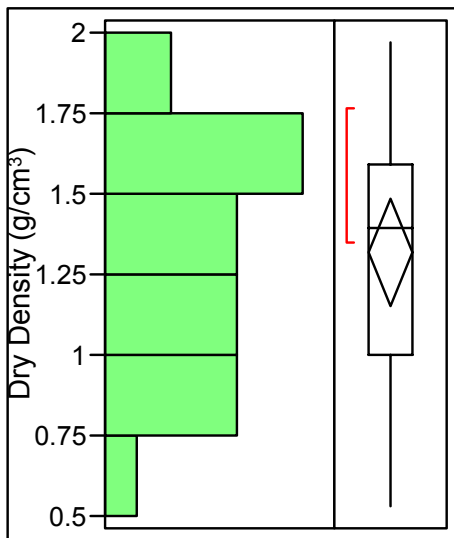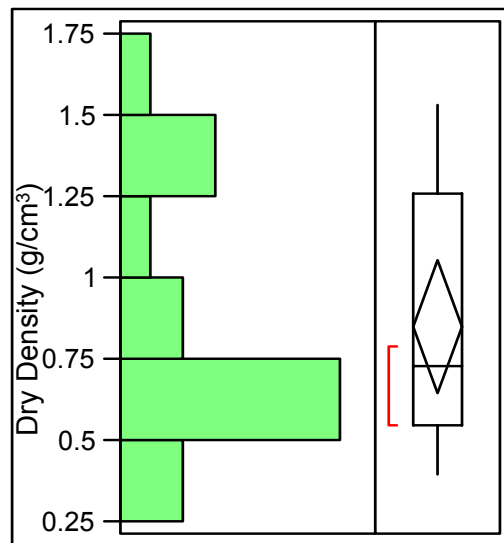
Notes

Gravel Quantiles

100.0%	maximum	1.6484
99.5%		1.6484
97.5%		1.6484
90.0%		1.6484
75.0%	quartile	1.6484
50.0%	median	1.6315
25.0%	quartile	1.3686
10.0%		1.3686
2.5%		1.3686
0.5%		1.3686
0.0%	minimum	1.3686

Gravel Moments

Mean	1.5495
Std Dev	0.1568917
Std Err Mean	0.0905815
upper 95% Mean	1.9392406
lower 95% Mean	1.1597594
N	3

Sand Quantiles

100.0%	maximum	1.9661
99.5%		1.9661
97.5%		1.9661
90.0%		1.7596
75.0%	quartile	1.5911
50.0%	median	1.3903
25.0%	quartile	1.0012
10.0%		0.8800
2.5%		0.5270
0.5%		0.5270
0.0%	minimum	0.5270

Sand Moments

Mean	1.3197762
Std Dev	0.3668893
Std Err Mean	0.0800618
upper 95% Mean	1.4867822
lower 95% Mean	1.1527702
N	21

Sand Quantiles

100.0%	maximum	1.5285
99.5%		1.5285
97.5%		1.5285
90.0%		1.4886
75.0%	quartile	1.2549
50.0%	median	0.7273
25.0%	quartile	0.5463
10.0%		0.4663
2.5%		0.3933
0.5%		0.3933
0.0%	minimum	0.3933

Silt Moments

Mean	0.8500354
Std Dev	0.3832591
Std Err Mean	0.0958148
upper 95% Mean	1.0542598
lower 95% Mean	0.6458111
N	16

Gravel

Sand

Silt

Dry Density (g/cm^3)

Grain Size 50th Percentile Distribution

Lower Passaic River Restoration Project

Figure A-1

February 2006
Draft

Detected Concentrations

Non-Detect Concentrations

	Total DDT Concentration Histogram	Figure A-2	
	Lower Passaic River Restoration Project	February 2006 Draft	MALCOLM PIRNIE

Detected Concentrations   Non-Detect Concentrations

2,3,7,8-TCDD Concentration Histogram

Lower Passaic River Restoration Project

Figure A-3

February 2006
Draft

Detected Concentrations

Non-Detect Concentrations

Detected Concentration
Quantiles

100.0%	maximum	4.4713
99.5%		4.4513
97.5%		4.2865
90.0%		4.1638
75.0%	quartile	4.0086
50.0%	median	3.7634
25.0%	quartile	3.5315
10.0%		2.9094
2.5%		2.0908
0.5%		1.9172
0.0%	minimum	1.0000

Detected Concentration
Moments

Mean	3.6676012
Std Dev	0.5176179
Std Err Mean	0.0209406
upper 95% Mean	3.7087255
lower 95% Mean	3.6264768
N	611

Non-Detect Concentration
Quantiles

100.0%	maximum	2.9868
99.5%		2.9868
97.5%		2.9542
90.0%		2.4440
75.0%	quartile	2.2553
50.0%	median	2.0792
25.0%	quartile	2.0414
10.0%		2.0000
2.5%		1.9542
0.5%		1.9542
0.0%	minimum	1.9542

Non-Detect Concentration
Moments

Mean	2.1787325
Std Dev	0.2231473
Std Err Mean	0.022204
upper 95% Mean	2.2227845
lower 95% Mean	2.1346804
N	101

Mercury Concentration Histogram

Lower Passaic River Restoration Project

Figure A-4

February 2006
Draft
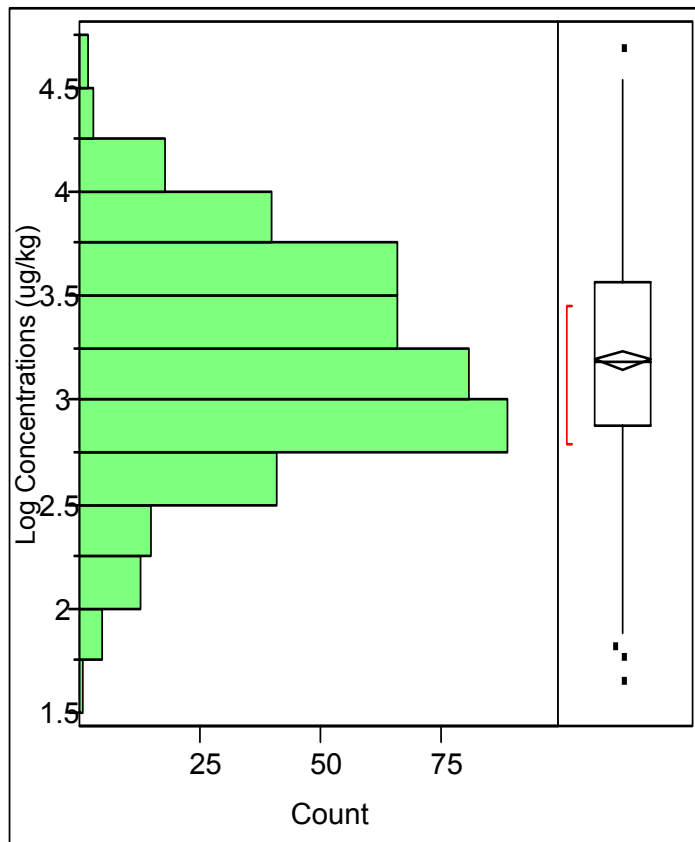
Detected Concentrations
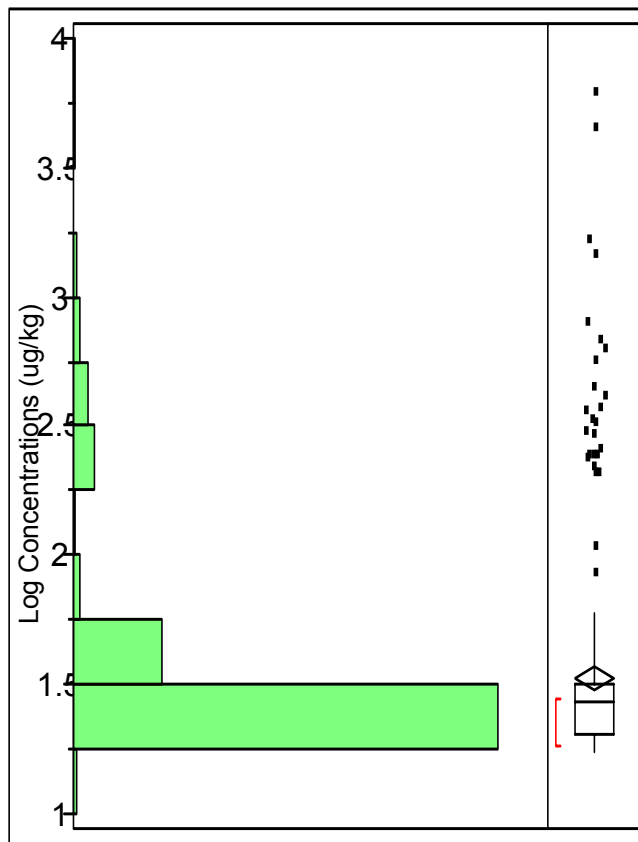
Non-Detect Concentrations

Notes

Detected Concentration
Quantiles

100.0%	maximum	4.6785
99.5%		4.5193
97.5%		4.1413
90.0%		3.8558
75.0%	quartile	3.5632
50.0%	median	3.1868
25.0%	quartile	2.8764
10.0%		2.6090
2.5%		2.0929
0.5%		1.7676
0.0%	minimum	1.6484

Non-Detect Concentration
Moments

Mean	3.1920687
Std Dev	0.5063567
Std Err Mean	0.0241396
upper 95% Mean	3.2395122
lower 95% Mean	3.1446251
N	440

Non-Detect Concentration
Quantiles

100.0%	maximum	3.7880
99.5%		3.7395
97.5%		2.8034
90.0%		1.7905
75.0%	quartile	1.5050
50.0%	median	1.4318
25.0%	quartile	1.3070
10.0%		1.2832
2.5%		1.2621
0.5%		1.2460
0.0%	minimum	1.2443

Non-Detect Concentration
Moments

Mean	1.5257253
Std Dev	0.400029
Std Err Mean	0.0244357
upper 95% Mean	1.5738364
lower 95% Mean	1.4776142
N	268

Total PCB Concentration Histogram

Figure A-5

February 2006
Draft

Lower Passaic River Restoration Project

US Army Corps
of Engineers®

MALCOLM
PIRNIE

Total DDT Mass Per Unit Area Histogram

Lower Passaic River Restoration Project

Figure A-6

February 2006
Draft

2,3,7,8-TCDD Mass Per Unit Area Histogram

Figure A-7

February 2006
Draft

Lower Passaic River Restoration Project

Mercury Mass Per Unit Area Histogram

Figure A-8

February 2006
Draft

Lower Passaic River Restoration Project
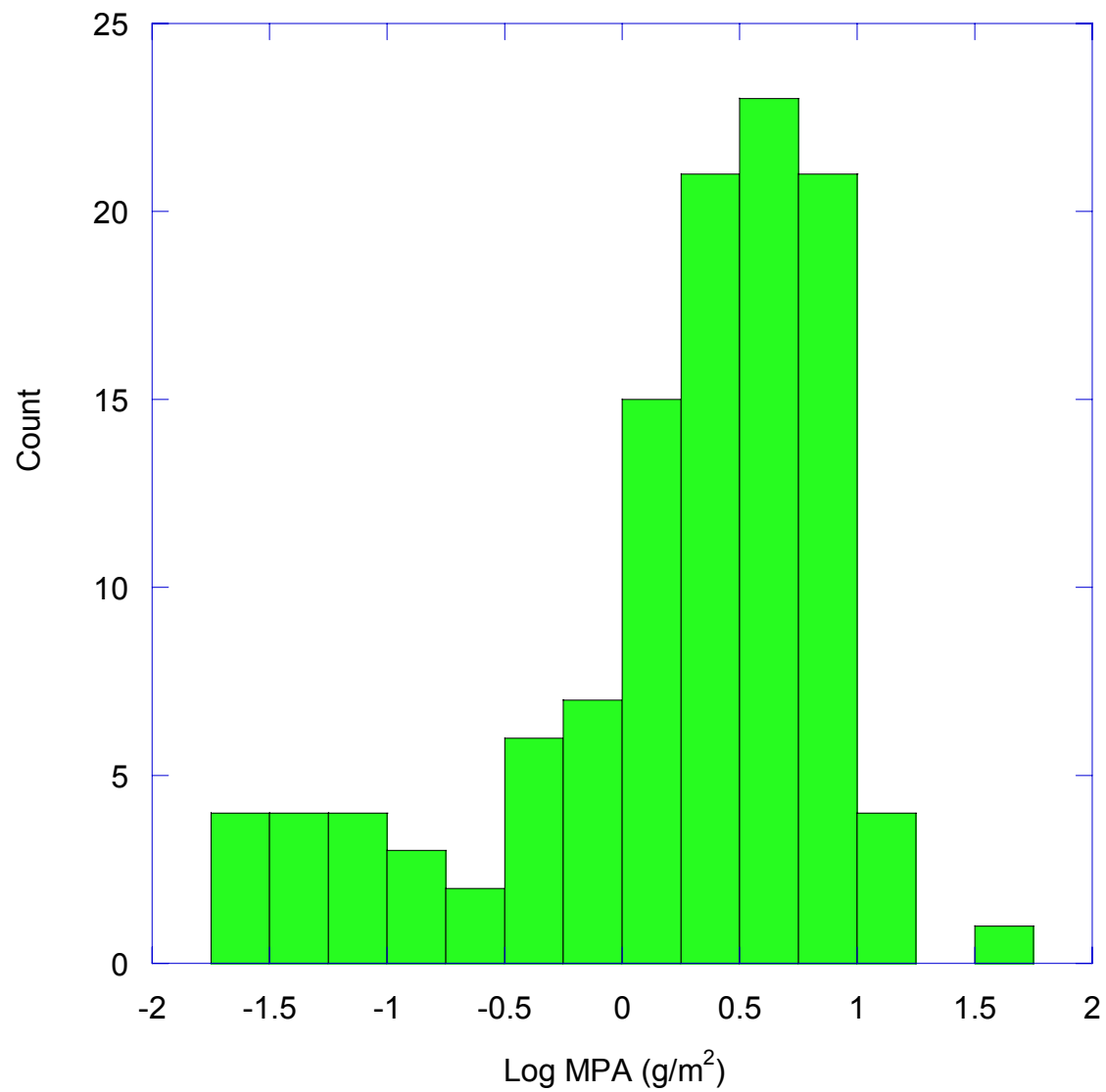
Total PCB Mass Per Unit Area Histogram

Figure A-9

February 2006
Draft

Lower Passaic River Restoration Project

Appendix B:

**Statistical Results for
Student's T-Test and Mann-Kendall Analyses**

Selected T-Test Results

Analyte	1963 interpolated results and 1995 depositional results							1963 intepolated results and all 1995 results							1995 depositional results and all 1995 results						
	t-stat	Mean		Variance		P (T<=t) one tail	t Critical one tail	t-stat	Mean		Variance		P (T<=t) one tail	t critical one tail	t-stat	Mean		Variance		P (T<=t) one tail	t critical one tail
		1963	1995	1963	1995				1963	1995	1963	1995				1995 (dep)	1995 (all)	1995 (dep)	1995 (all)		
As	8.05	27.35	8.55	72.73	3.66	0.00	1.76	7.06	27.35	10.54	72.73	44.72	0.00	1.75	2.33	8.55	10.54	3.66	44.72	0.01	1.67
Ba	8.61	307.40	166.86	2382.33	1347.82	0.00	1.71	9.94	307.40	161.64	2382.33	4124.35	0.00	1.72	0.44	166.86	161.64	1347.82	4124.35	0.33	1.70
Cd	11.05	18.77	4.89	21.06	1.03	0.00	1.76	10.77	18.77	5.13	21.06	9.46	0.00	1.75	0.58	4.89	5.13	1.03	9.46	0.28	1.67
Cr	8.14	623.76	126.74	51377.21	793.69	0.00	1.77	7.66	623.76	153.41	51377.21	9951.92	0.00	1.76	2.10	126.74	153.41	793.69	9951.92	0.02	1.67
Cu	9.57	502.73	186.79	14178.02	1076.80	0.00	1.75	6.80	502.73	226.12	14178.02	61020.92	0.00	1.69	1.47	186.79	226.12	1076.80	61020.92	0.07	1.66
Pb	12.24	668.35	304.57	10816.96	1543.19	0.00	1.74	10.52	668.35	333.68	10816.96	21550.86	0.00	1.72	1.56	304.57	333.68	1543.19	21550.86	0.06	1.66
Hg	10.85	11.30	2.84	8.01	0.50	0.00	1.75	10.18	11.30	3.33	8.01	3.73	0.00	1.75	1.77	2.84	3.33	0.50	3.73	0.04	1.68
Ni	10.60	83.27	37.34	220.32	42.42	0.00	1.73	6.92	83.27	45.27	220.32	1372.95	0.00	1.68	1.90	37.34	45.27	42.42	1372.95	0.03	1.66
Ag	7.59	10.69	4.56	6.69	2.26	0.00	1.72	8.11	10.69	4.54	6.69	7.92	0.00	1.73	0.04	4.56	4.54	2.26	7.92	0.48	1.70
TPAH	2.40	49.25	20.81	1587.19	96.76	0.02	1.78	-0.35	49.25	60.58	1587.19	87642.30	0.37	1.66	1.29	20.81	60.58	96.76	87642.30	0.10	1.66
TPH	4.56	949.74	233.85	300742.18	19415.34	0.00	1.76	1.79	949.74	522.15	300742.18	3210562.88	0.04	1.67	1.53	233.85	522.15	19415.34	3210562.88	0.06	1.66
TCDD	4.38	0.01	0.00	0.00	0.00	0.00	1.78	4.15	0.01	0.00	0.00	0.00	0.00	1.78	2.47	0.00	0.00	0.00	0.00	0.01	1.66
TPCB	4.22	6.84	1.01	14.60	0.65	0.00	1.86	4.04	6.84	1.32	14.60	3.38	0.00	1.89	0.91	1.01	1.32	0.65	3.38	0.19	1.75

Mann-Kendall Results

Analyte	1963 interpolated result		1995 depositional results		1995 all results	
	S (result)	N (# of data points)	S (result)	N (# of data points)	S (result)	N (# of data points)
As	-33	14	-8	14	-1246	95
Ba	7	14	35	14	244	92
Cd	-11	14	-8	14	-447	95
Cr	-17	14	-17	14	-828	95
Cu	-3	14	1	14	-352	95
Pb	5	14	32	14	788	90
Hg	-33	14	-17	14	-1027	92
Ni	5	14	-9	14	-471	95
Ag	-1	14	12	14	-238	82
TPAH	14	12	7	12	657	93
TPH	-8	13	8	13	181	95
TCDD	4	13	8	13	242	95
TPCB	-10	8	12	8	147	90

NOTES:

Statistical results for TCDD do not include values obtained at Location ID 231. The concentration in 1963 was not characteristic of the rest of the dataset, and is considered an outlier.

Appendix C:

HydroQual Water Column Data Compilation

HydroQual Inc. memorandum dated December 8, 2005 presenting water column data available from the CARP and project databases for select chemicals.

December 8, 2005

Bruce Fidler, P.E.
Senior Associate
Malcolm Pirnie, Inc.
17-17 Route 208 North
Fair Lawn, NJ 07410   MPIN0021

Dear Bruce:

Please find enclosed HydroQual's final product relative to the Preliminary Geochemical Evaluation-Scope of Work of May 16, 2005 (WAD 5, WO 7.3). As you will notice, and as explained below, some of the deliverables are missing, mainly as a result of missing data or information.

Under deliverable number 5 of the May 2005 Scope of Work, HydroQual was contracted to generate plots that show the ratio of the suspended-phase (mg contaminant per kilogram solid) to the surficial sediment concentration (mg contaminant per kilogram solid) versus river mile. In order to generate these plots, concurrent data are required (i.e., surficial sediment samples collected at the same time as the water column samples). In spite of the abundance of sediment data, only few water column measurements were reported in the PREmis and the CARP databases. For example in the case of total DDT, two instances exist where both suspended phase and surficial concentrations were available for the same locations; however, the sampling dates for these samples were not coincident. The same scenario is true for the other contaminants examined. In the absence of concurrent measurements, the calculated ratios would be difficult to interpret, and thus plots for deliverable number 5 are not provided in the final product. However, we have generated plots showing discrete suspended phase and surficial sediment contaminant data.

Under deliverable number 3 of the May 2005 Scope of Work, HydroQual was contracted to generate plots that show the ratio of the dissolved-phase (mg contaminant per liter) to the total concentration (mg contaminant per liter) versus river mile. In the CARP database, the New Jersey data set (e.g., NJSIT) contains dissolved-phase and suspended-phase data for most toxic chemicals. However, the suspended phase occasionally was not reported while for other chemicals (e.g., Dioxin and Furans) only the suspended phase was reported. Meanwhile, the New York data set (e.g., Simon Litten) of the CARP database contains total, dissolved, and suspended phase information for some chemicals and some time periods. Since only partial information was available, the total-phase was either not reported or could not be reconstructed with the available data.

To create the required plots, total-phase for each contaminant from the New Jersey database was calculated from the available suspended-phase and dissolved-phase data while the total-phase from the New York database was used as reported or re-constructed when possible. Therefore, the

"missing" total-phase points that appear between deliverable number 3 and 4 represent cases where the total-phase was either not reported or could not be reconstructed because either the dissolved or the suspended phase data were not provided.
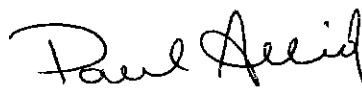
Under deliverable number 4 of the May 2005 Scope of Work, HydroQual was contracted to generate plots that show the ratio of the dissolved-phase (mg contaminant per liter) to the suspended-phase (mg contaminant per kilogram solid) versus river mile, including the corresponding salinity information. There were no concurrent water column concentration data and salinity data reported in the CARP or PREmis databases.

In addition, the PREmis database provided insufficient description of the historical water column data. Contaminants were reported as surface water composite, surface water particulate or surface water. In spite of a joint HydroQual-Malcolm Pirnie effort, it was not possible to define the descriptions in terms of total, dissolved and particulate components. As a consequence, deliverables 2, 3, 4 and 5 were not generated for the PREmis data. Instead, HydroQual has generated for each contaminant a plot showing the PREmis water column data "as reported" and the CARP data with different sampling years versus river mile.

If you have any question, please call me at 201-529-5151.

Very truly yours,

HYDROQUAL, INC.

Paul J. Anid, Dr.Sc.
Principal Scientist

PJA/mag
MPI'0021/FIDLER08DEC05LTR
Cc: Jim Fitzpatrick, HydroQual, Inc.
        AmyMarie Accardi-Dey, Malcolm Pirnie

**CARP PLOTS
(CARP_Passaic.pdf)**

Passaic River
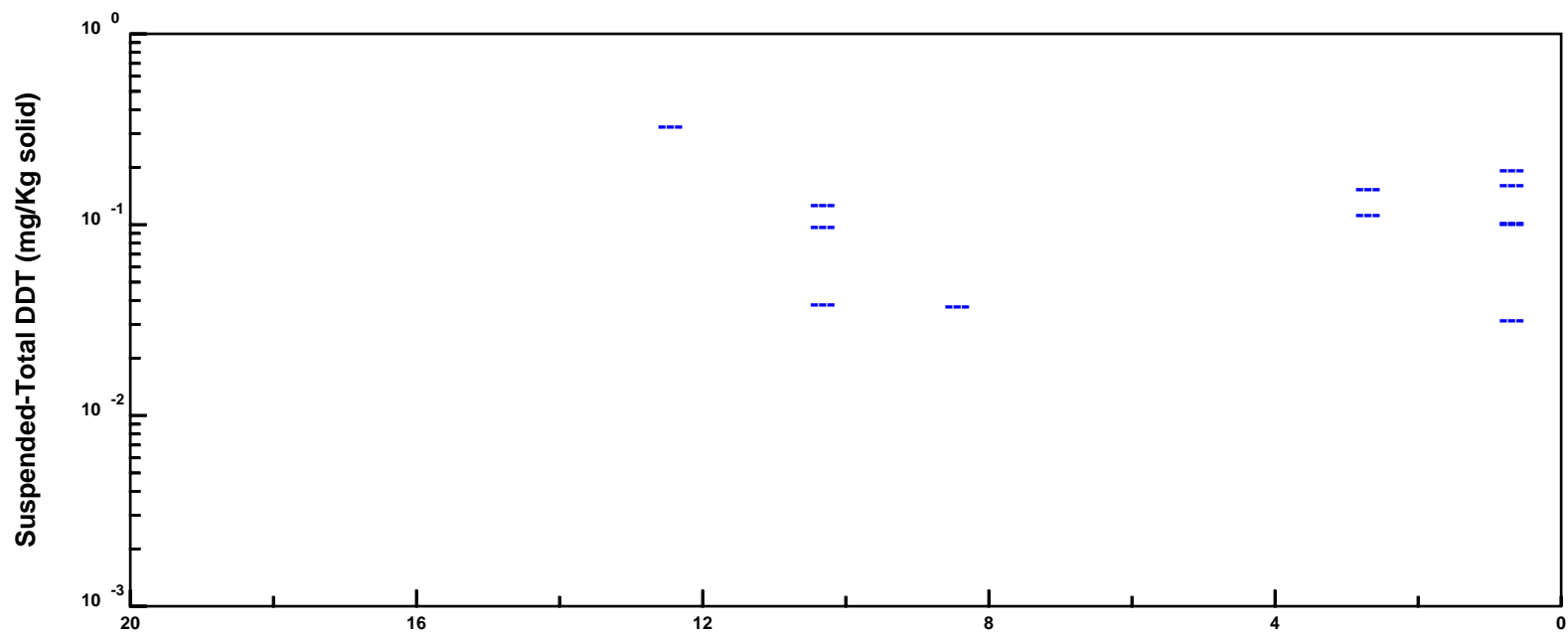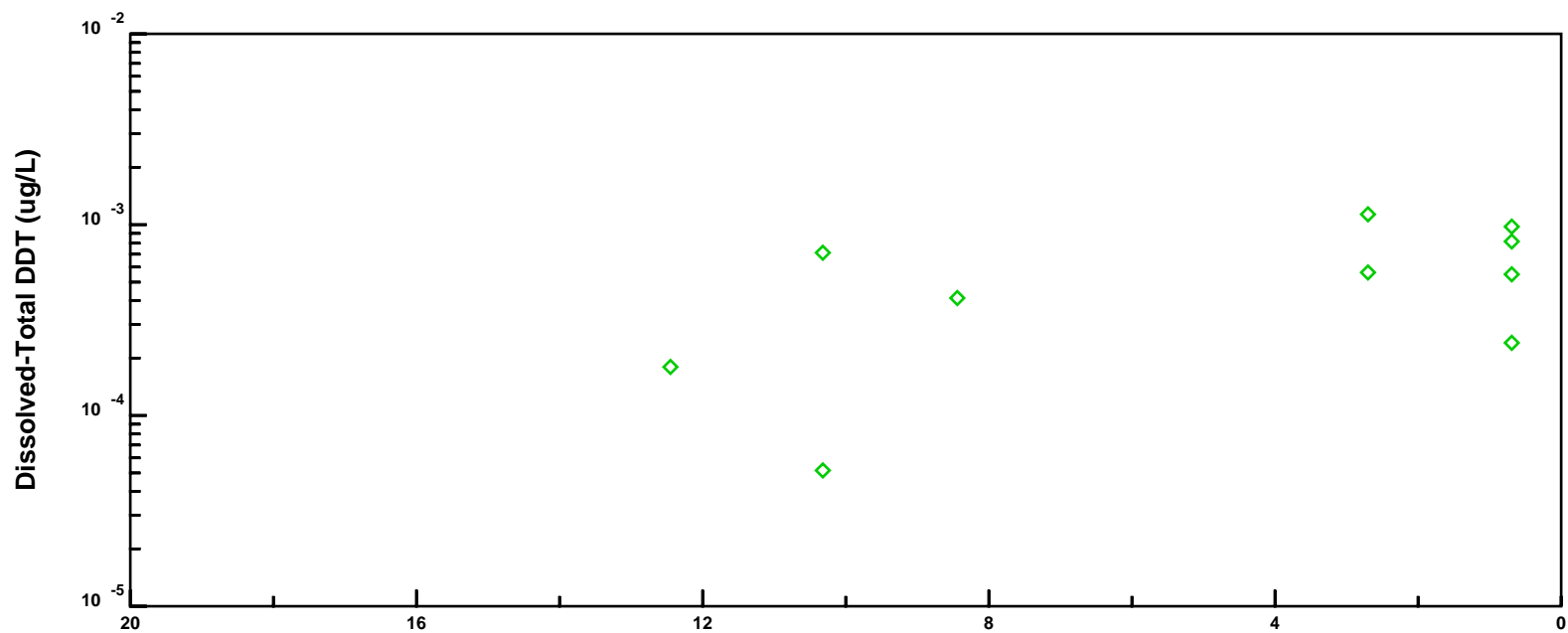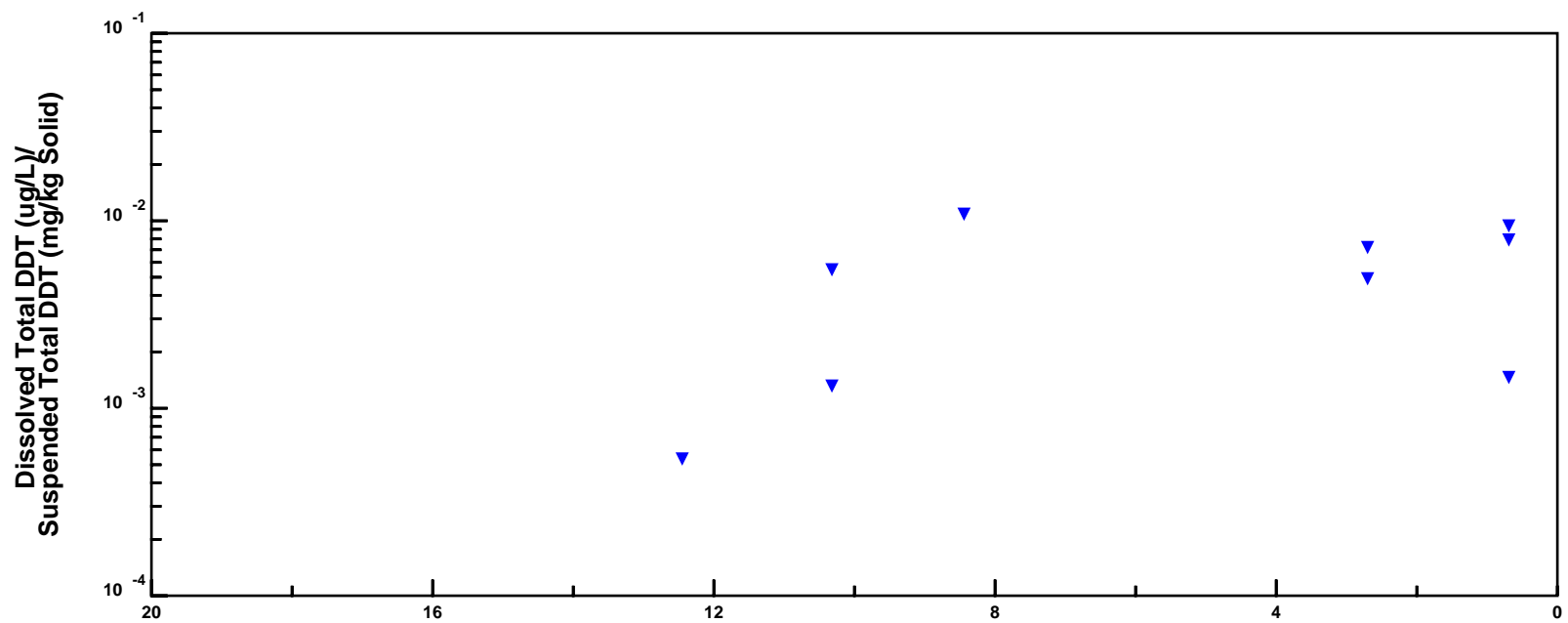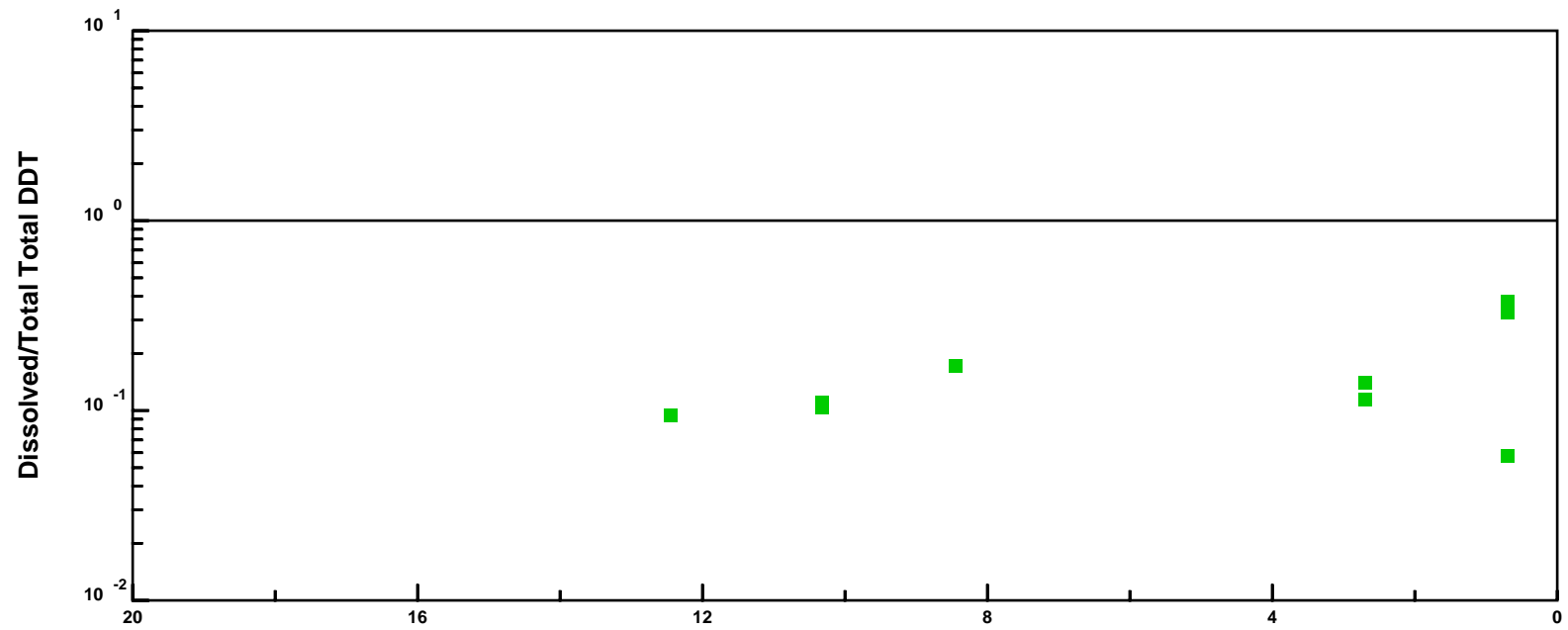
CARP 1998-2000

CARP 1998-2000

Dissolved-Total DDT (ug/L)

Suspended-Total DDT (mg/Kg solid)

Mile From Confluence of the Passaic River with Newark Bay

Passaic River

CARP 1998-2000

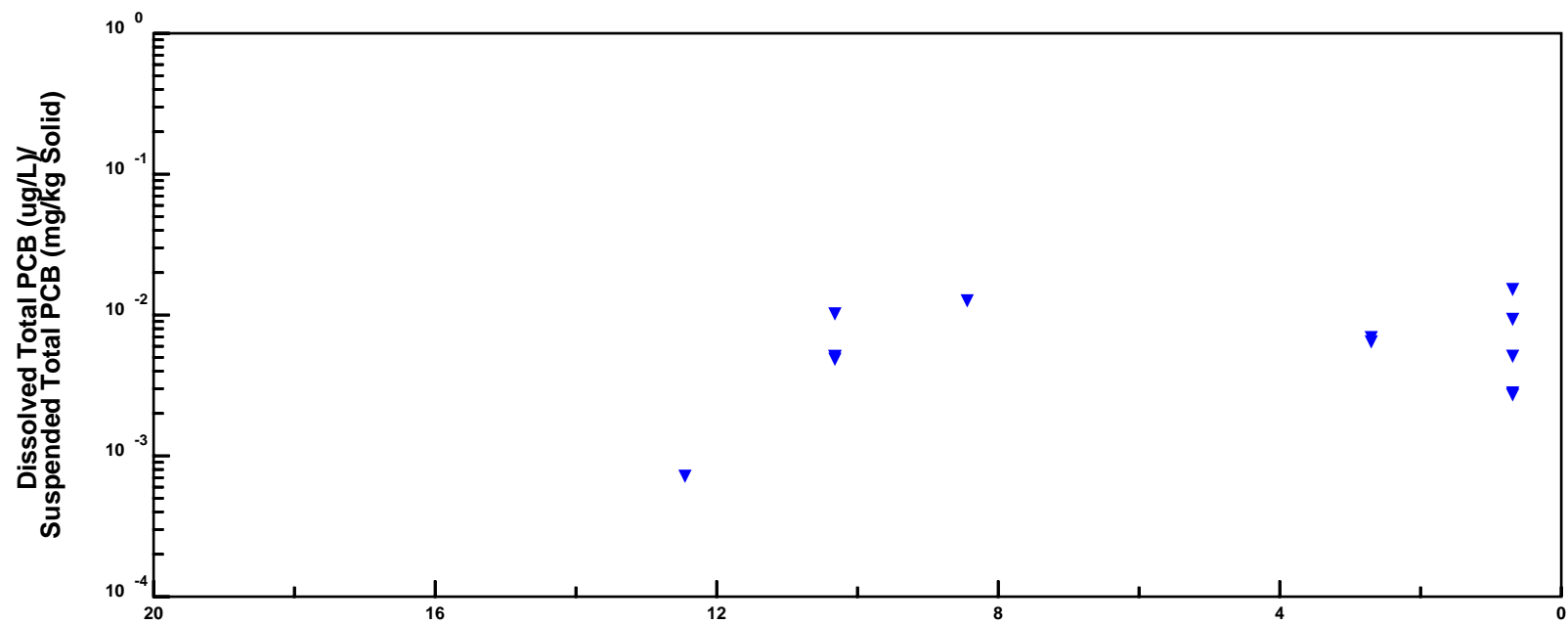CARP 1998-2000
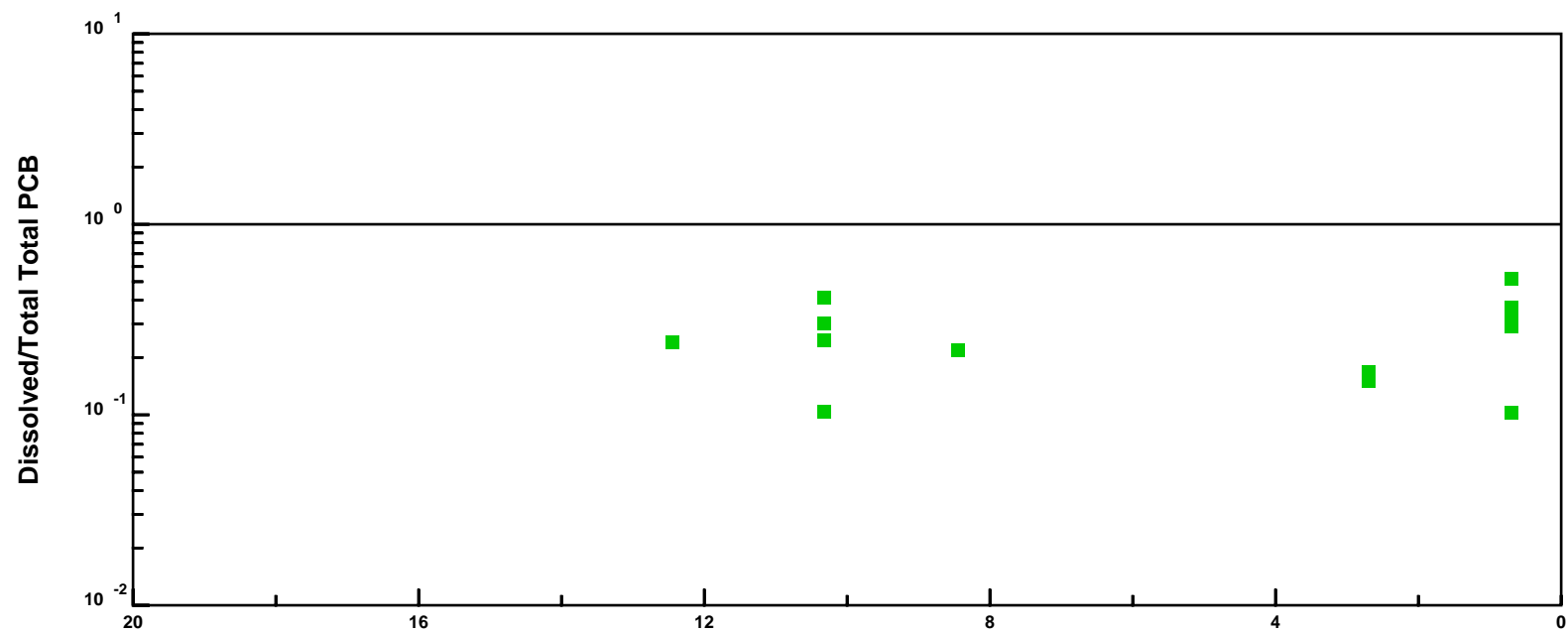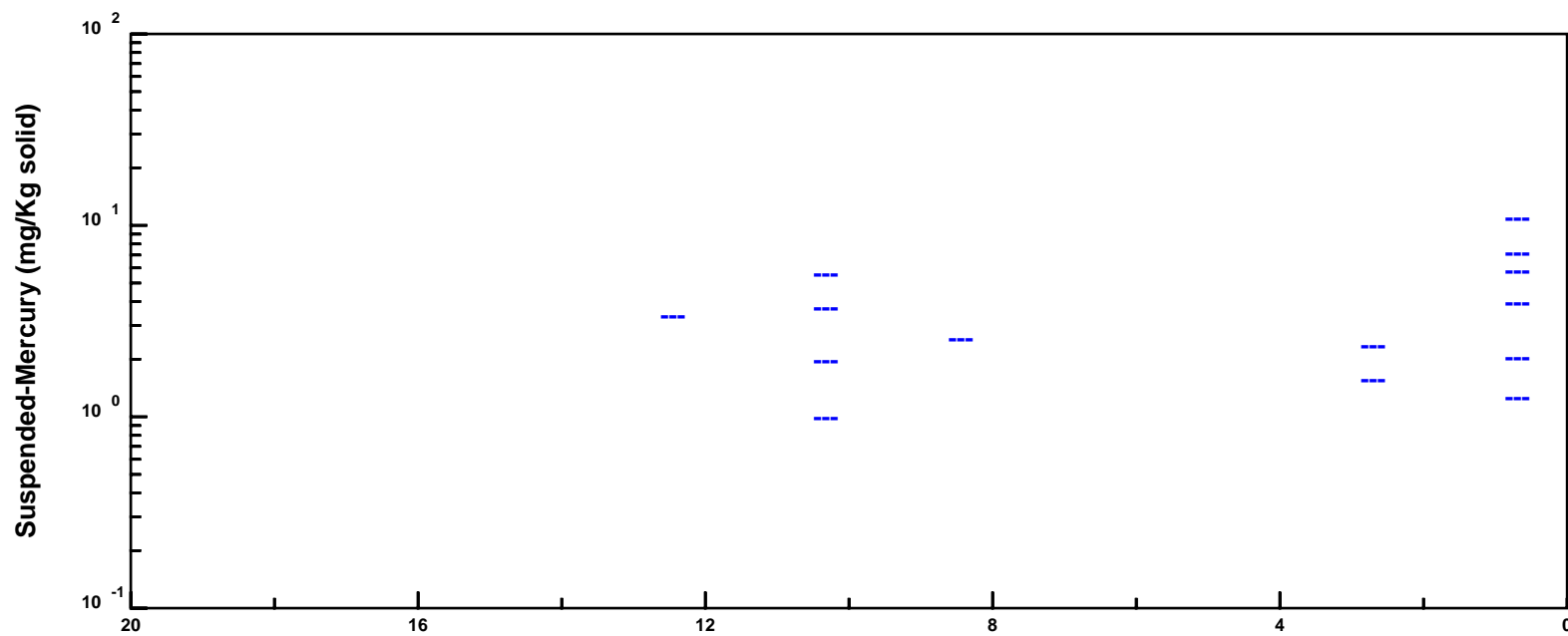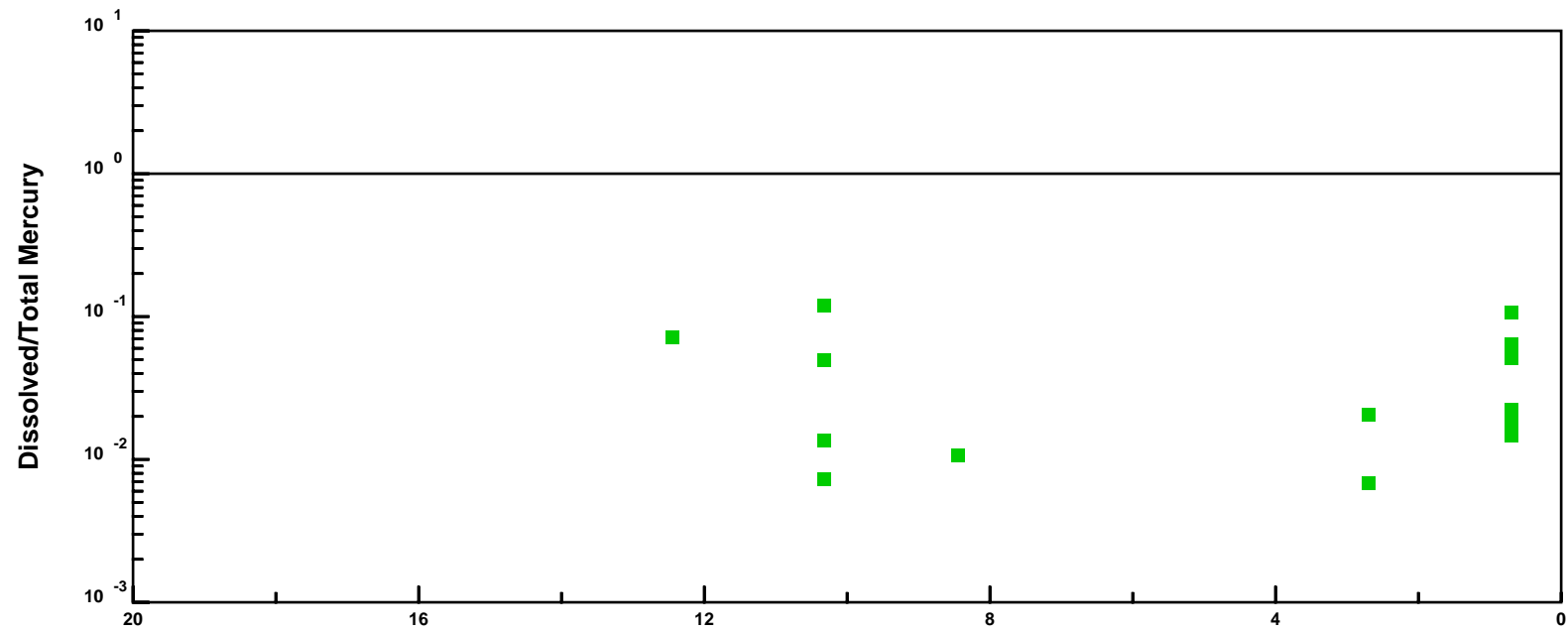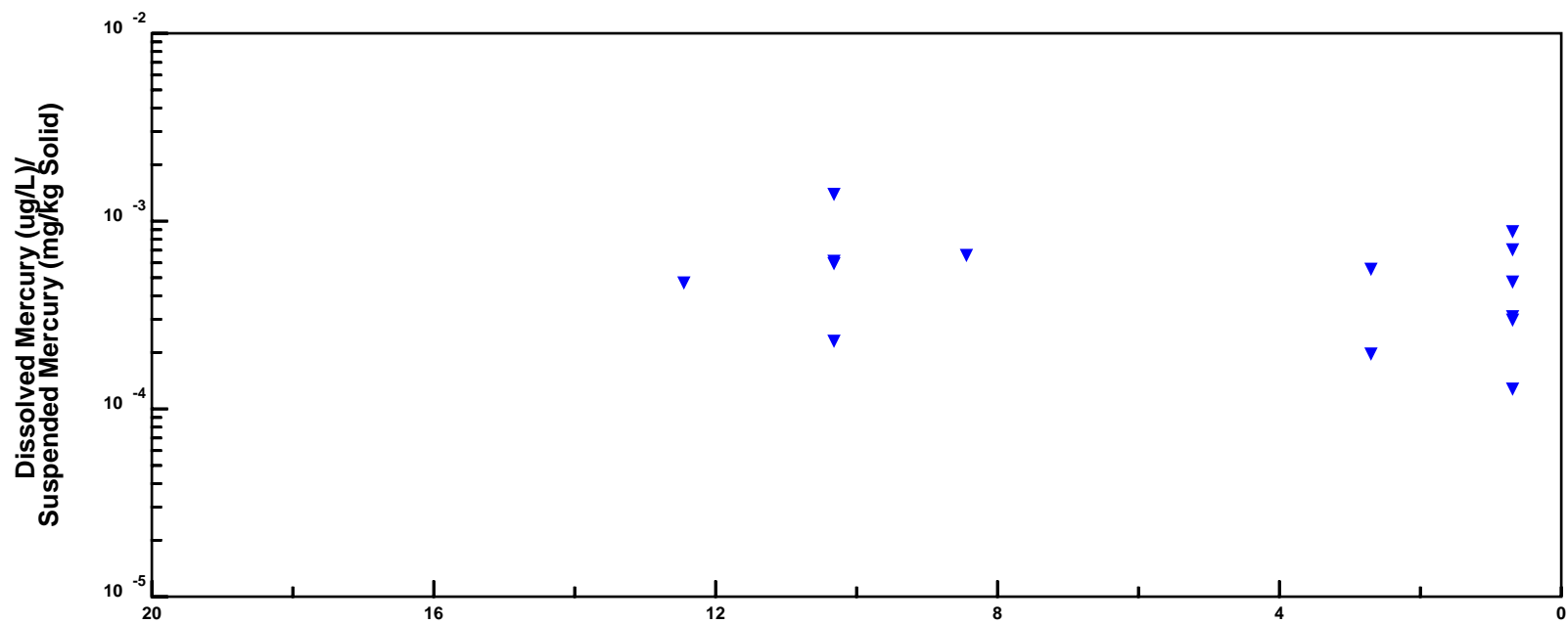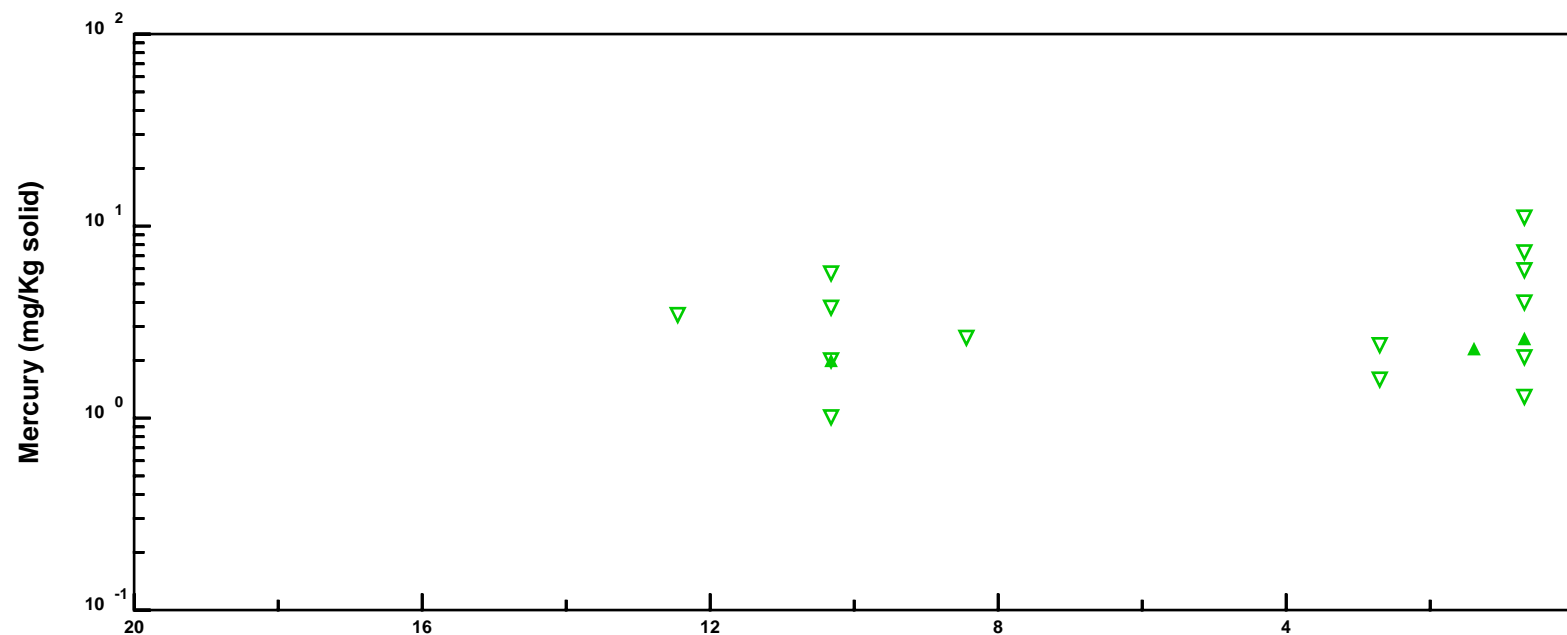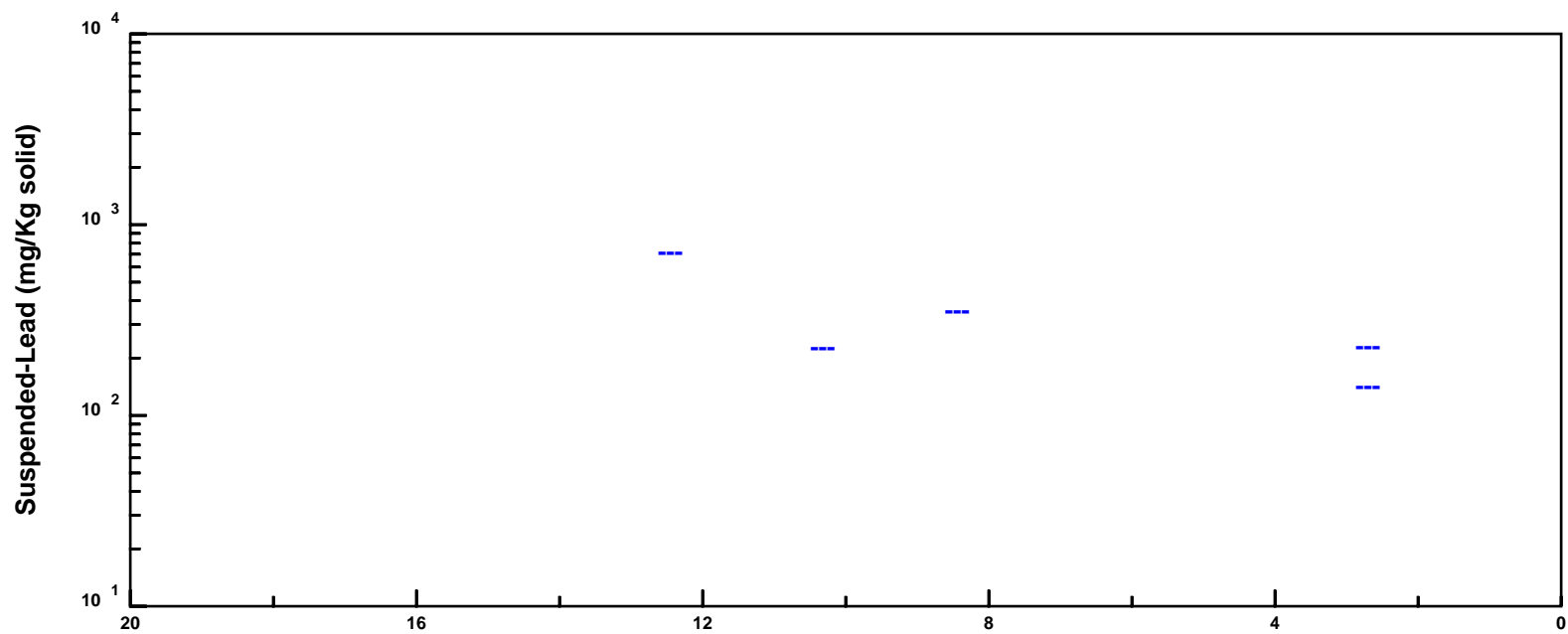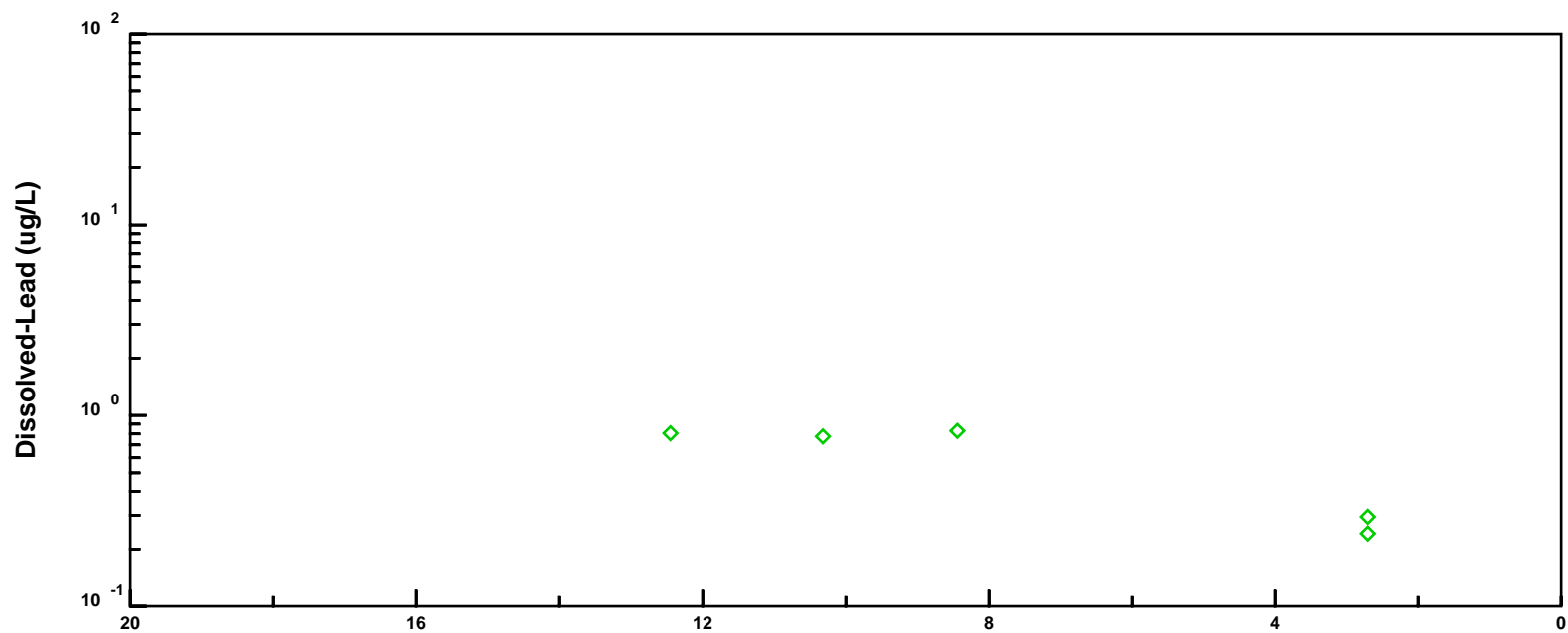
Mile From Confluence of the Passaic River with Newark Bay
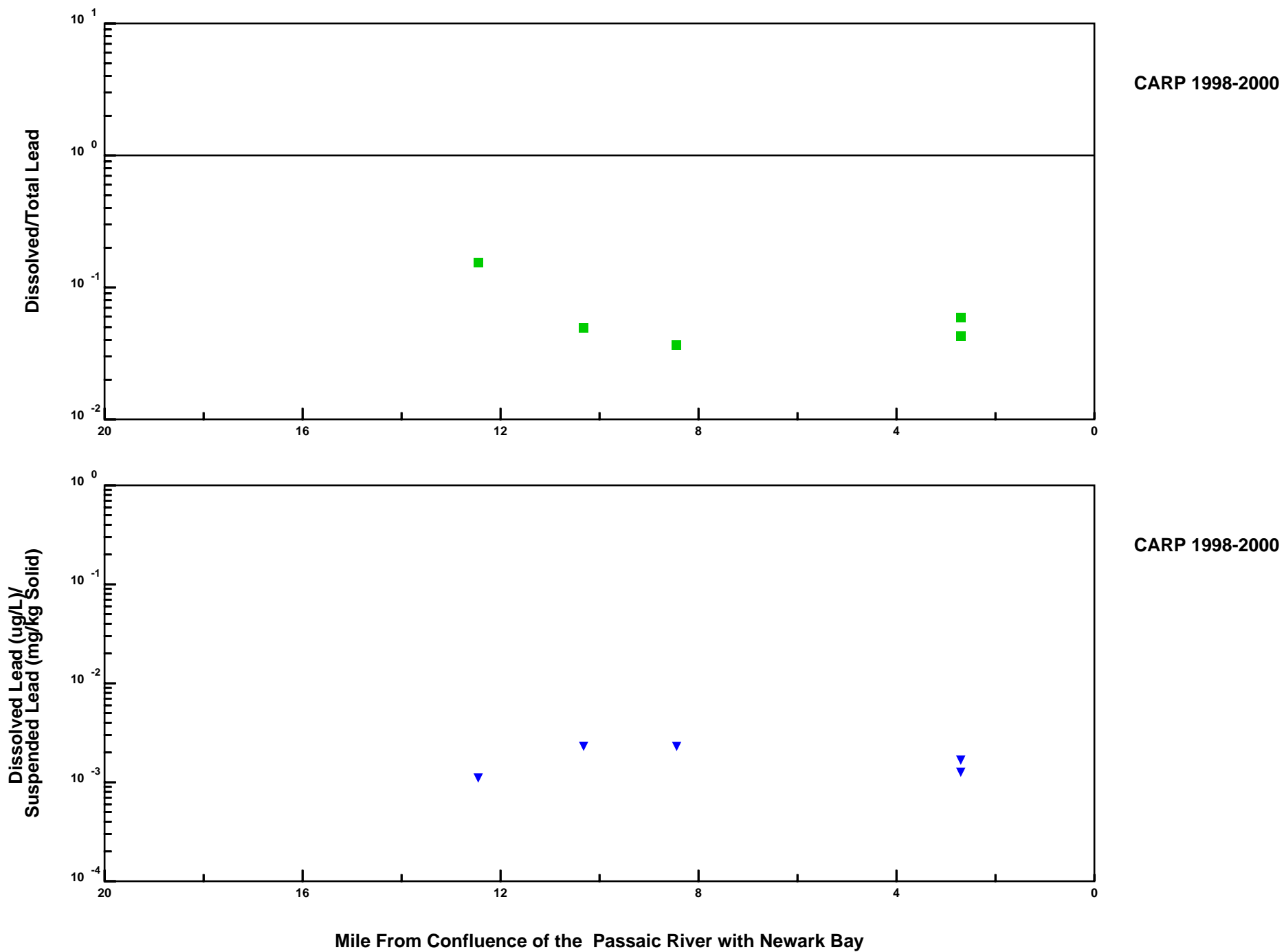
Passaic River

CARP 1998-2000

Total DDT (mg/Kg solid)

Mile From Confluence of the Passaic River with Newark Bay

▲ Surficial Sediment (0-0.1 cm)
▽ Suspended-phase

Passaic River

CARP 1998-2000

CARP 1998-2000

Mile From Confluence of the Passaic River with Newark Bay
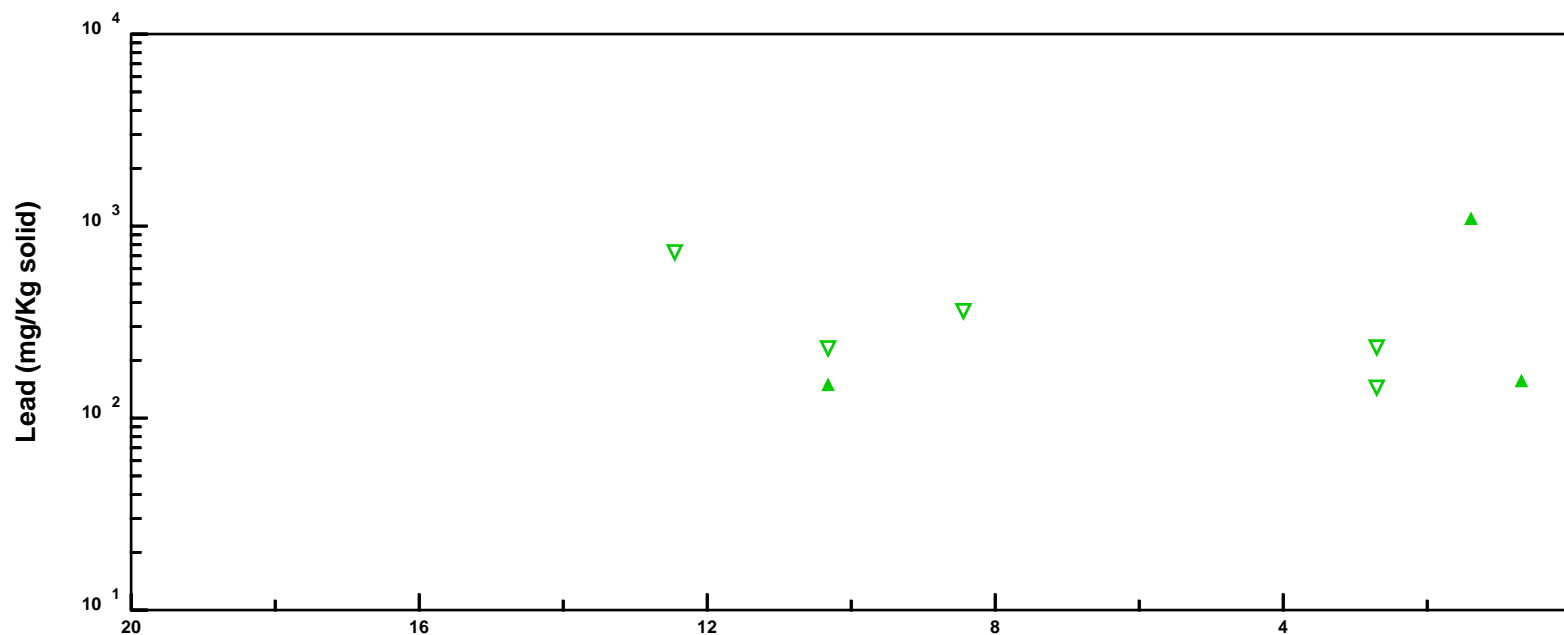
Passaic River

CARP 1998-2000

CARP 1998-2000

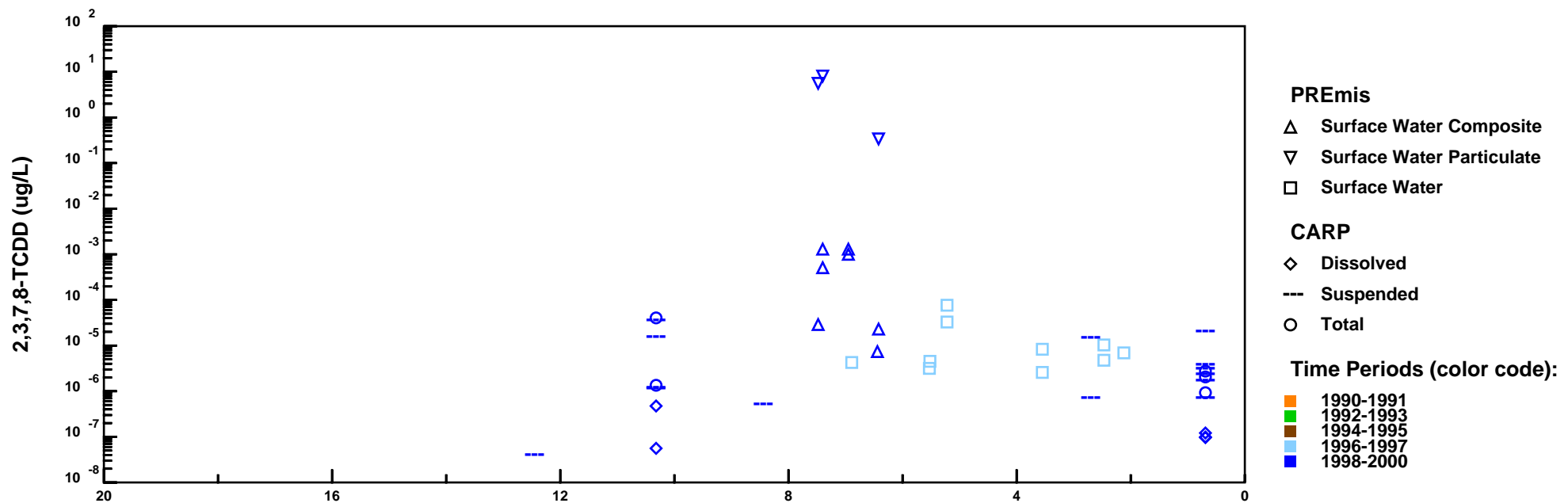Mile From Confluence of the Passaic River with Newark Bay

Passaic River

CARP 1998-2000

2,3,7,8-TCDD (mg/Kg solid)
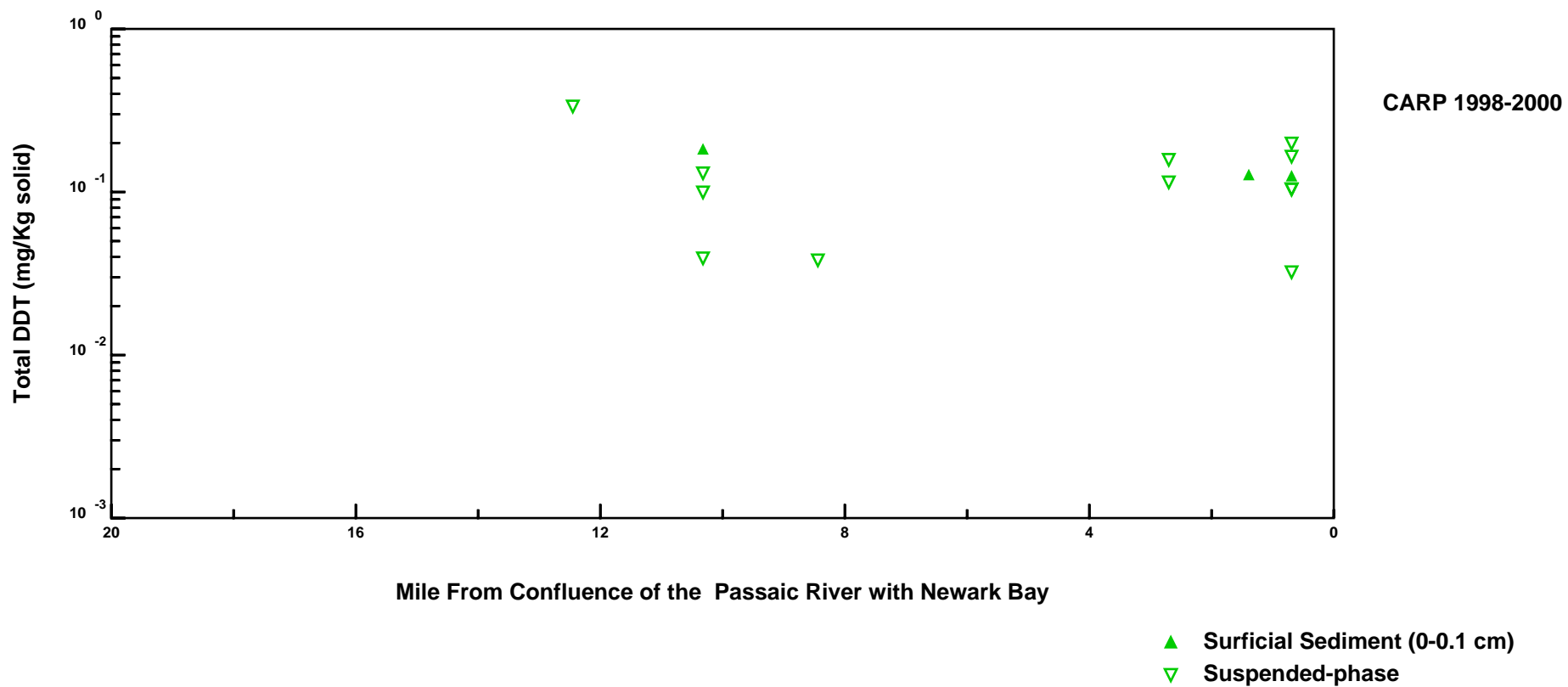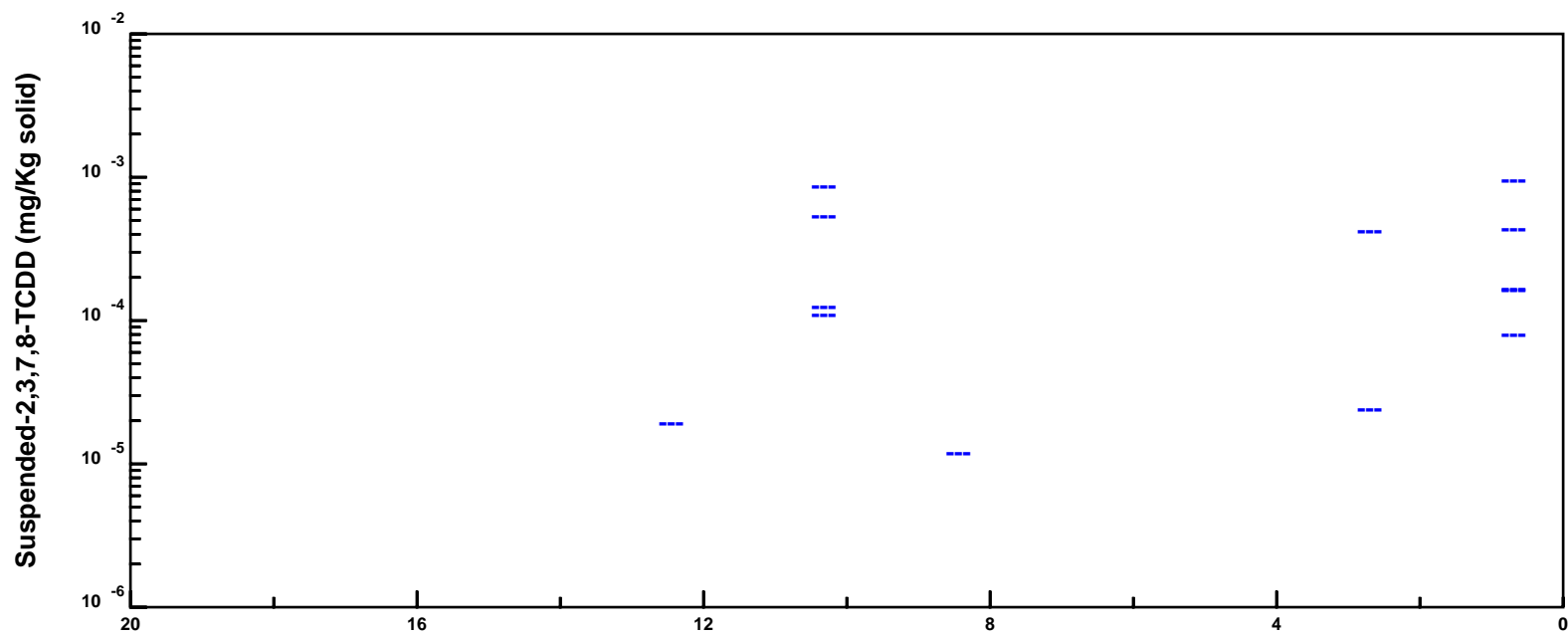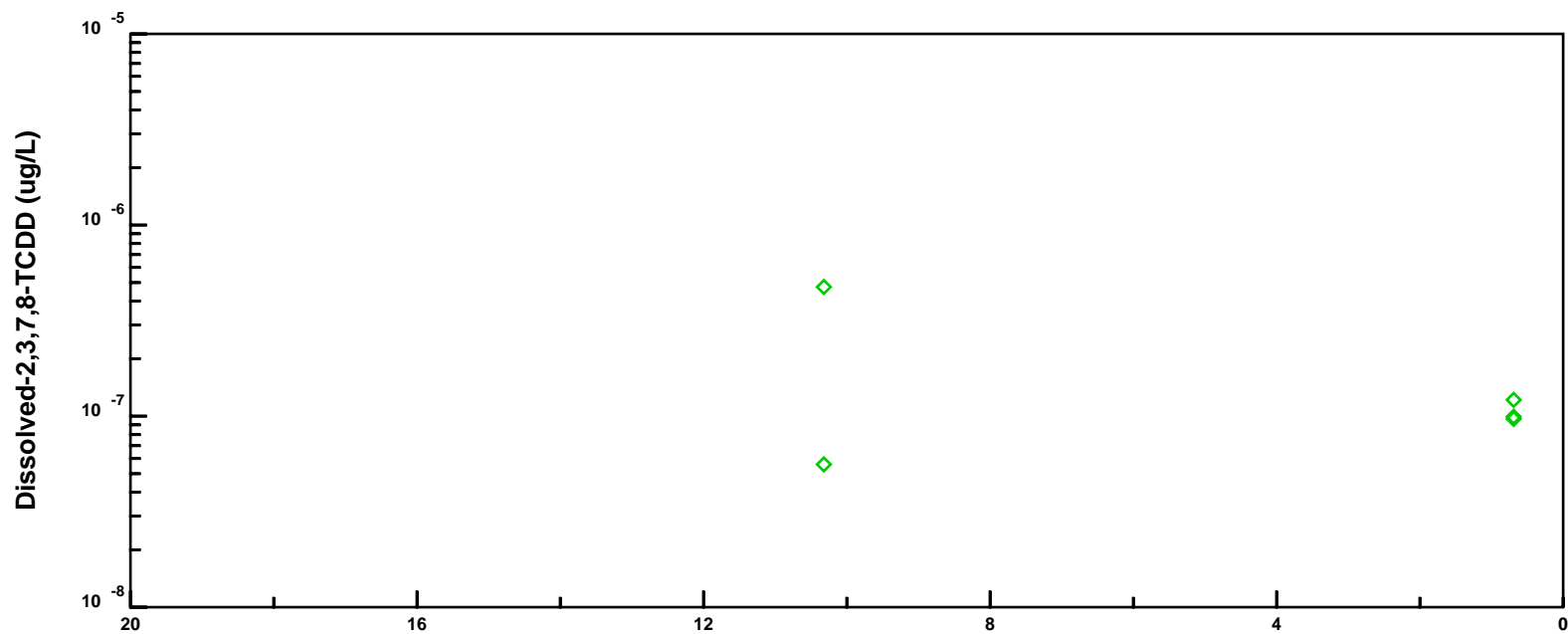
Mile From Confluence of the Passaic River with Newark Bay
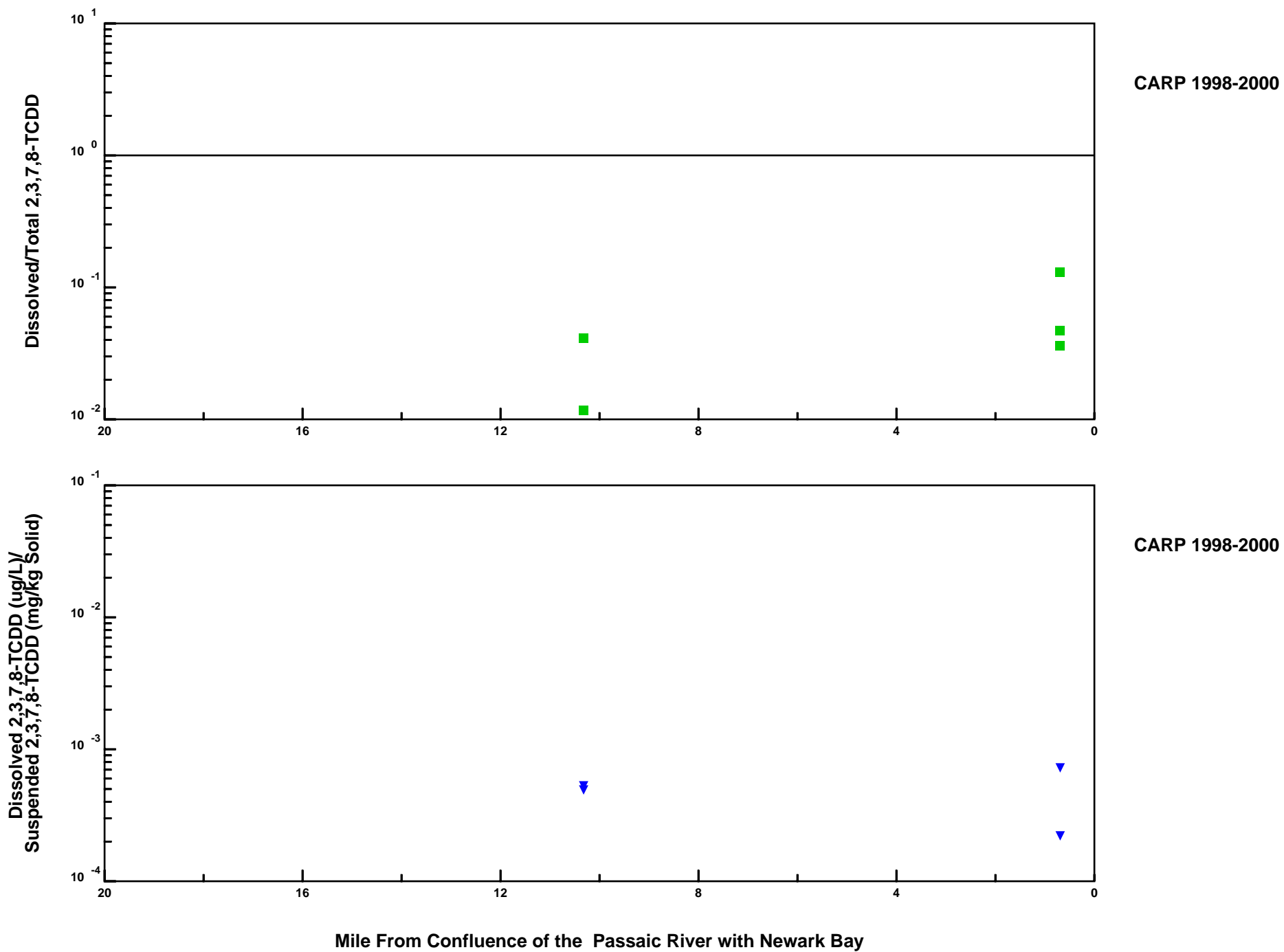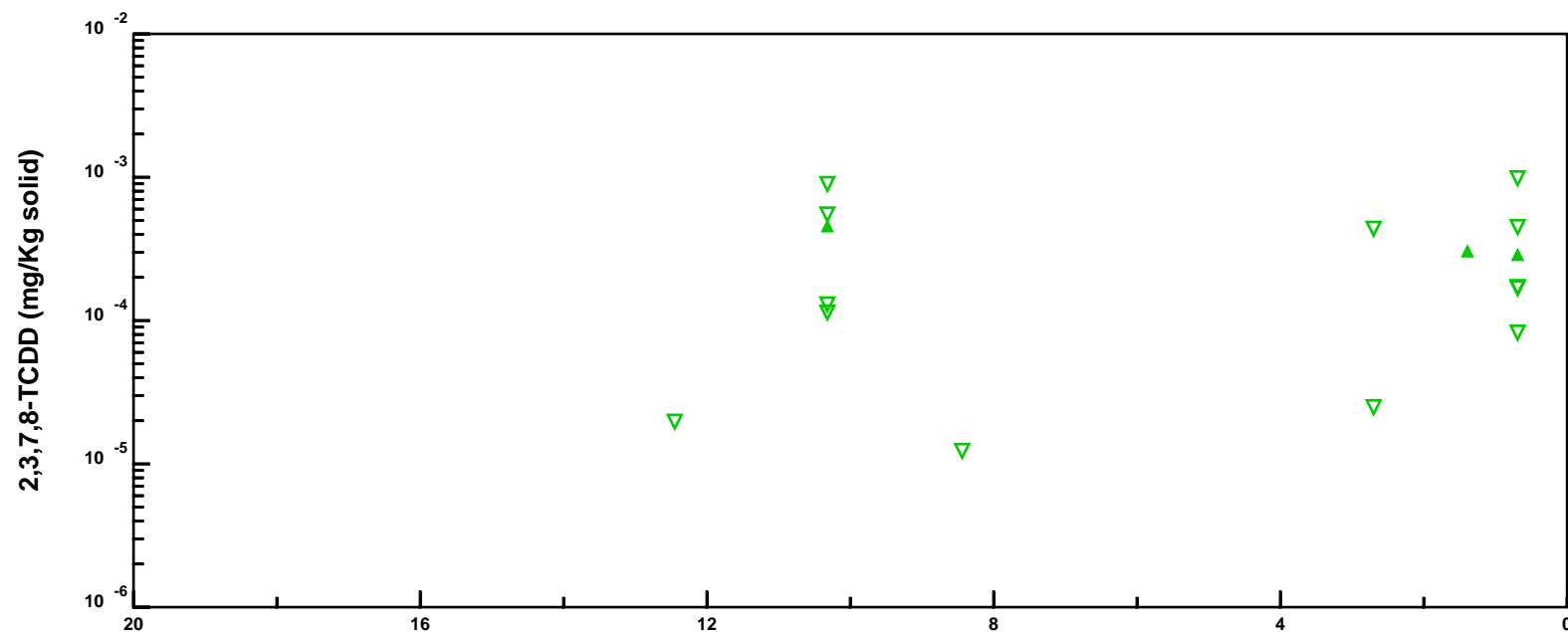
▲ Surficial Sediment (0-0.1 cm)
▽ Suspended-phase

Passaic River

CARP 1998-2000
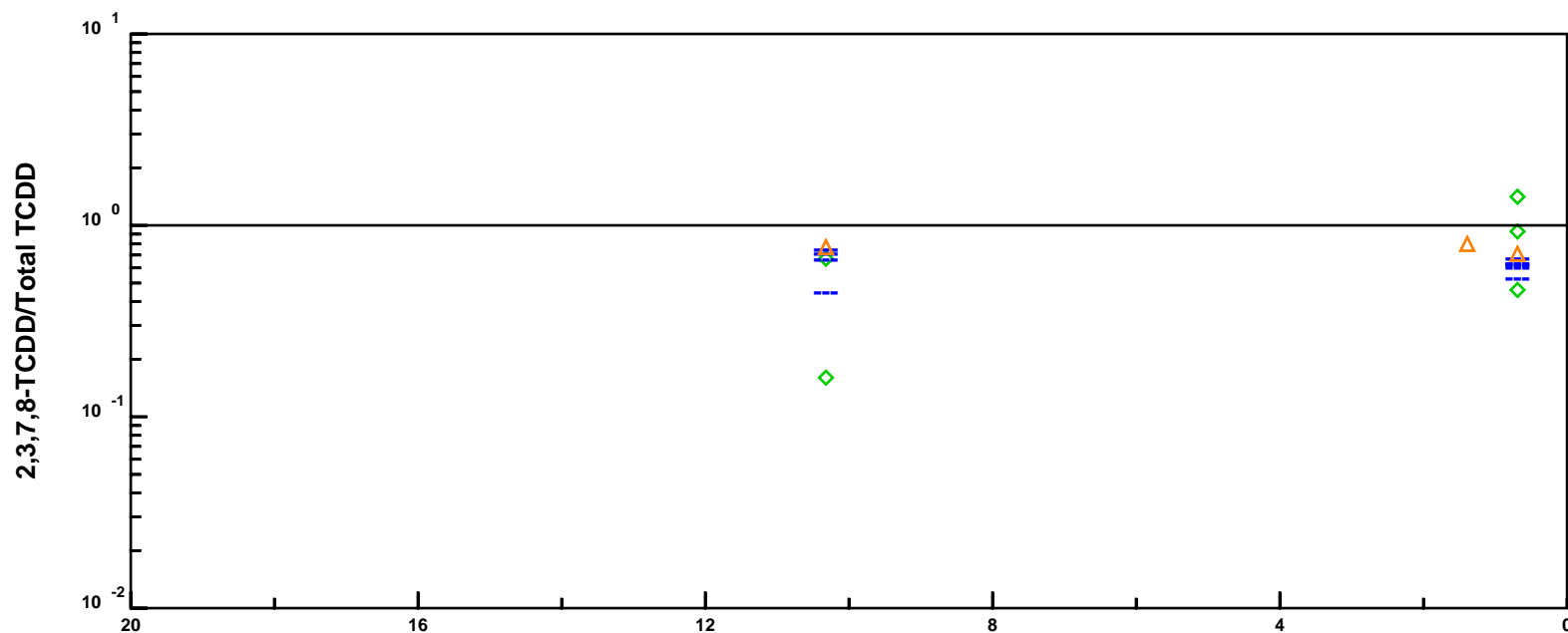
◇ Dissolved 2,3,7,8-TCDD/Dissolved Total TCDD
--- Suspended 2,3,7,8-TCDD/Suspended Total TCDD
△ Surficial Sediment 2,3,7,8-TCDD/Surficial Sediment Total TCDD (0-0.1 cm)

Passaic River

CARP 1998-2000

CARP 1998-2000

Dissolved-Total PAH (ug/L)

Suspended-Total PAH (mg/Kg solid)

Mile From Confluence of the Passaic River with Newark Bay

Passaic River

CARP 1998-2000

CARP 1998-2000
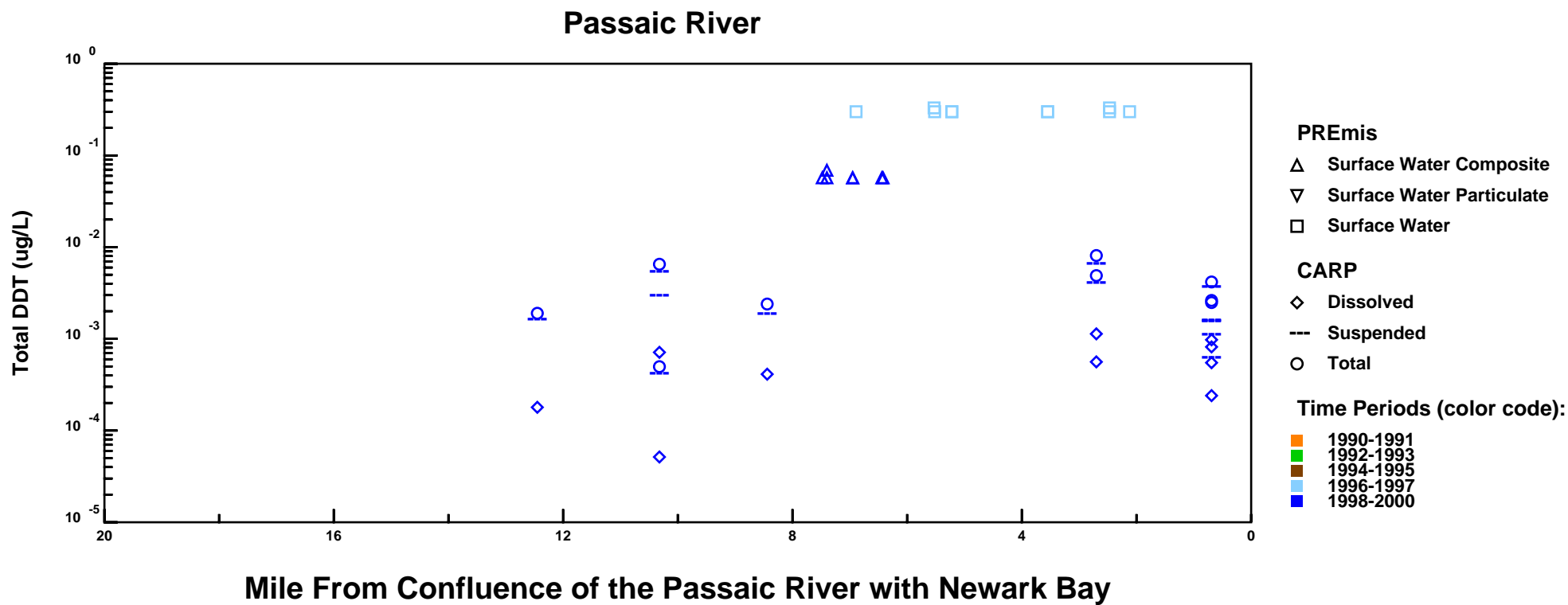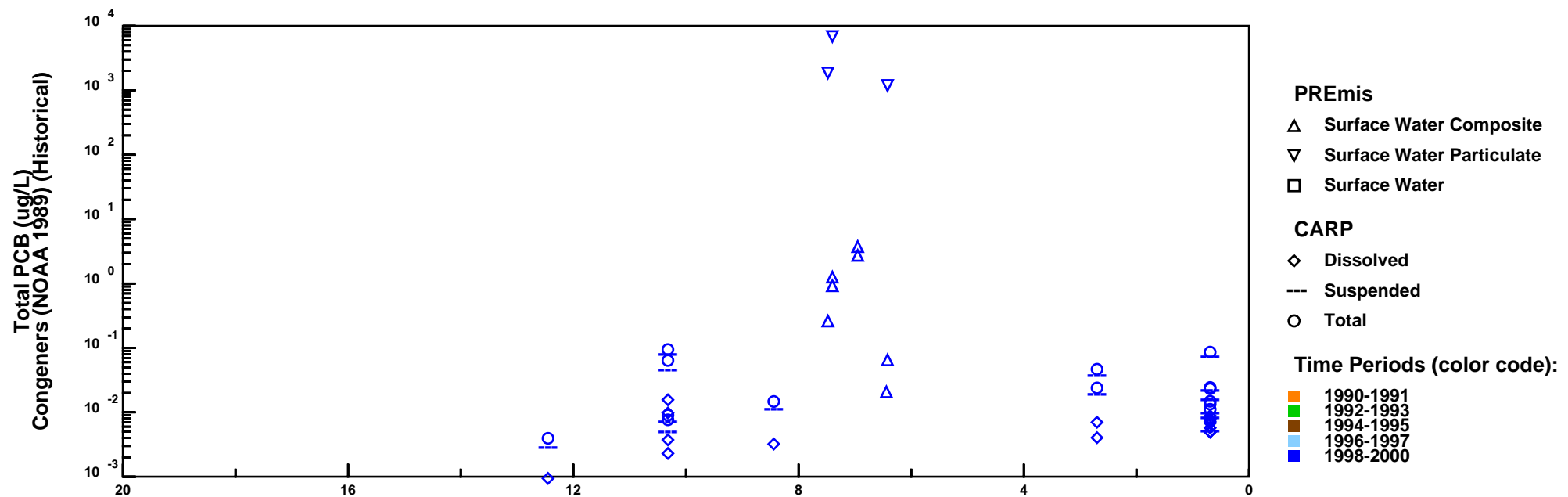
Dissolved/Total Total PAH

Dissolved Total PAH (ug/L)/
Suspended Total PAH (mg/kg Solid)

Mile From Confluence of the Passaic River with Newark Bay

Passaic River

CARP 1998-2000

Total PAH (mg/Kg solid) vs. Mile From Confluence of the Passaic River with Newark Bay

▲ Surficial Sediment (0-0.1 cm)
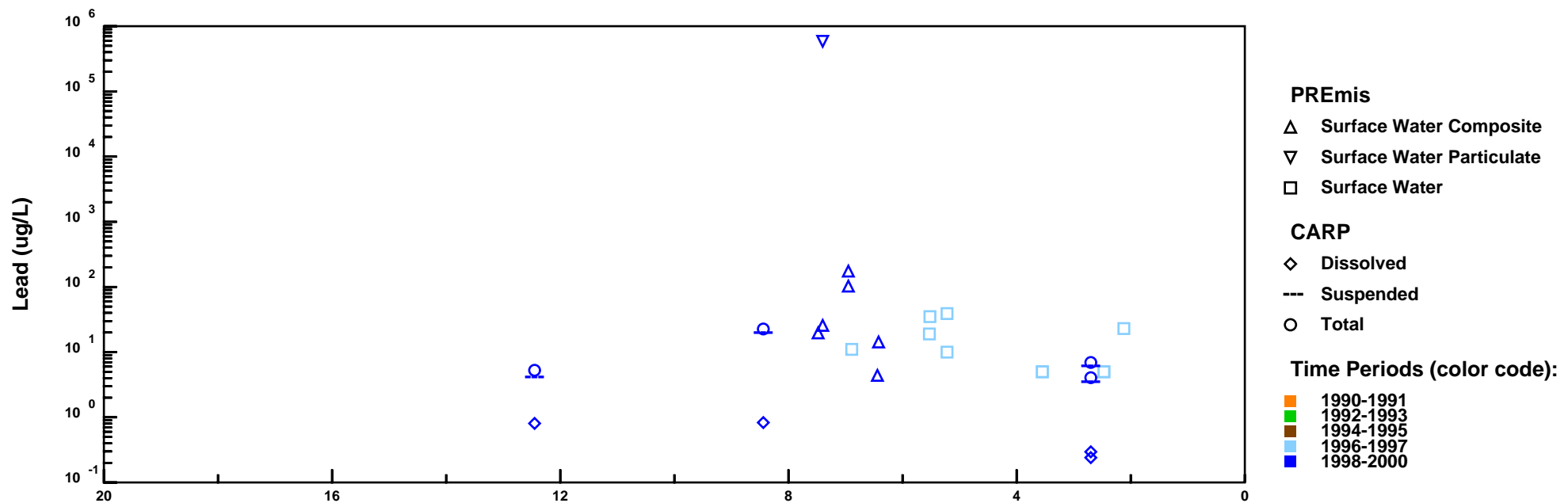▽ Suspended-phase

Passaic River

Passaic River

CARP 1998-2000

CARP 1998-2000

Mile From Confluence of the Passaic River with Newark Bay

Passaic River

CARP 1998-2000

Total PCB (mg/Kg solid)

Mile From Confluence of the Passaic River with Newark Bay

▲ Surficial Sediment (0-0.1 cm)

▽ Suspended-phase

Passaic River

CARP 1998-2000

CARP 1998-2000

Passaic River

CARP 1998-2000

CARP 1998-2000

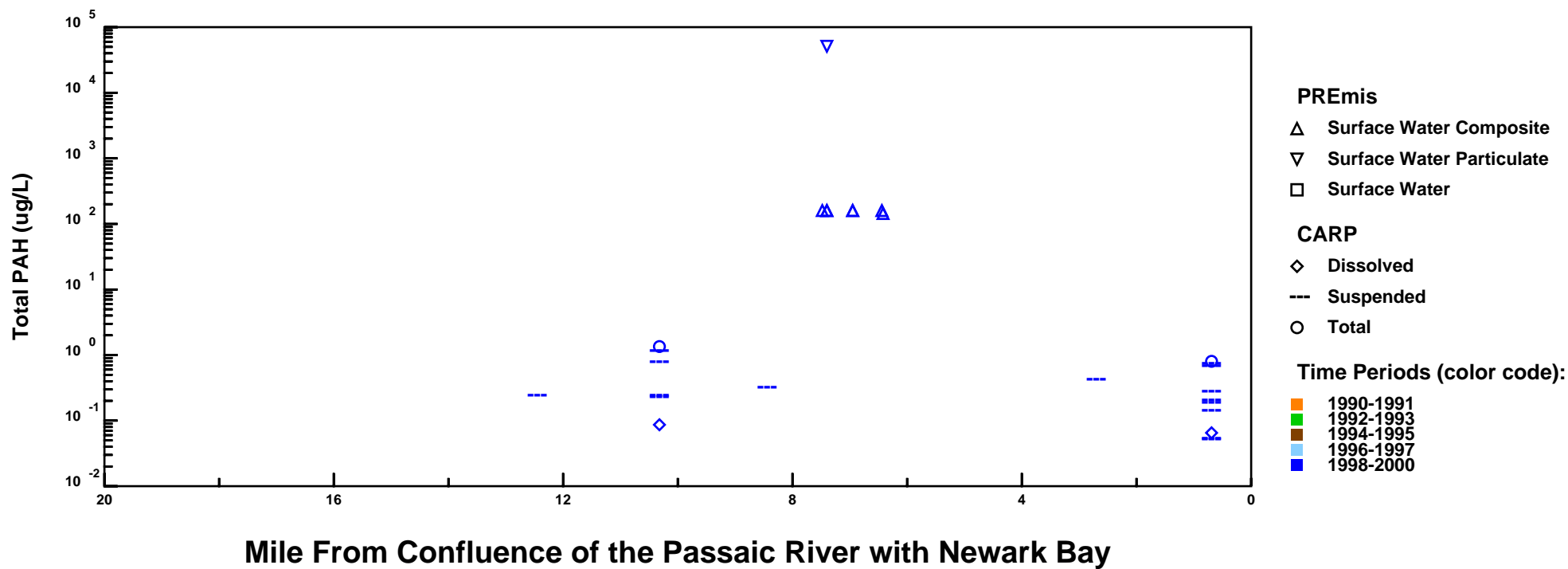Mile From Confluence of the Passaic River with Newark Bay

Passaic River

CARP 1998-2000
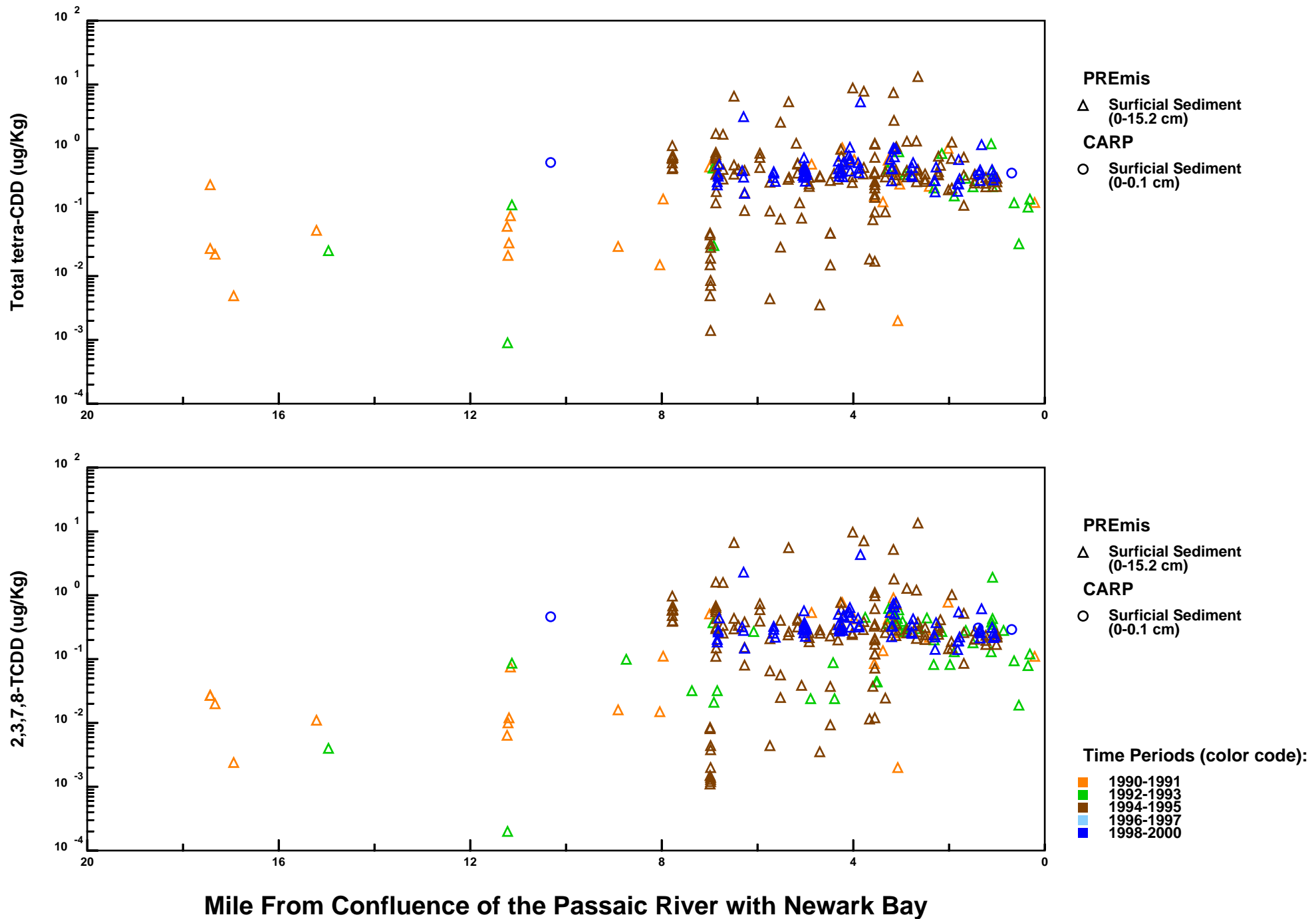
Mercury (mg/Kg solid)

Mile From Confluence of the Passaic River with Newark Bay

▲ Surficial Sediment (0-0.1 cm)
▽ Suspended-phase

Passaic River

CARP 1998-2000

CARP 1998-2000

Mile From Confluence of the Passaic River with Newark Bay

Passaic River

CARP 1998-2000

Lead (mg/Kg solid)

Mile From Confluence of the Passaic River with Newark Bay

▲ Surficial Sediment (0-0.1 cm)
▽ Suspended-phase

PREmis/CARP WATER COLUMN PLOTS
(PREmis_Passaic_WaterColumn.pdf)

Passaic River
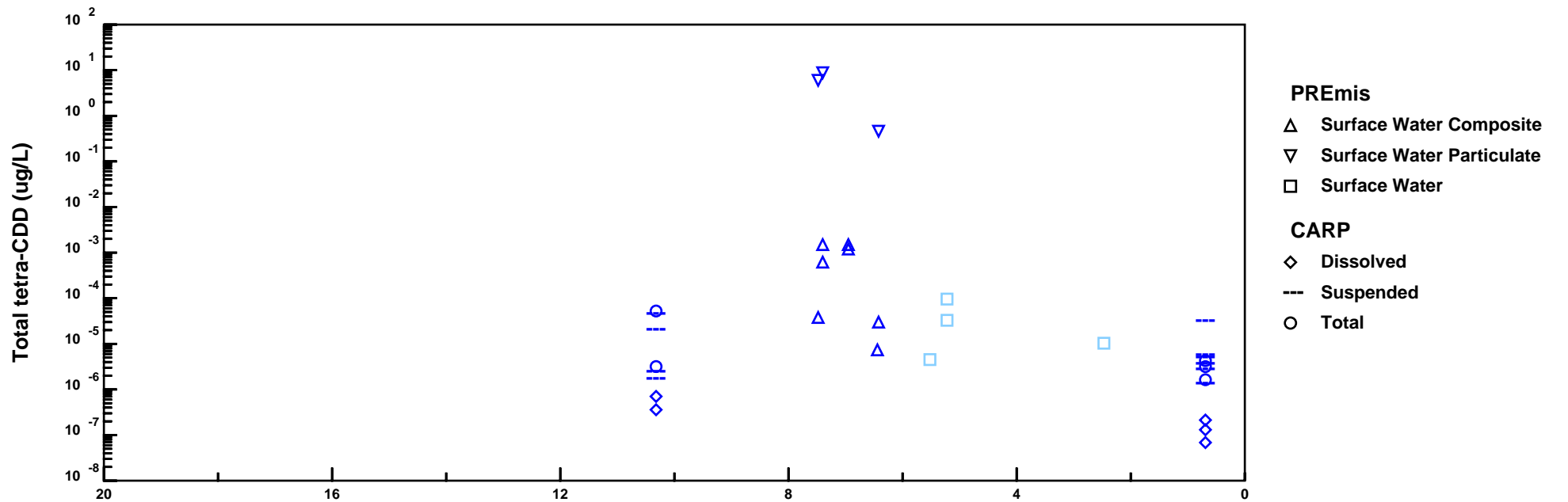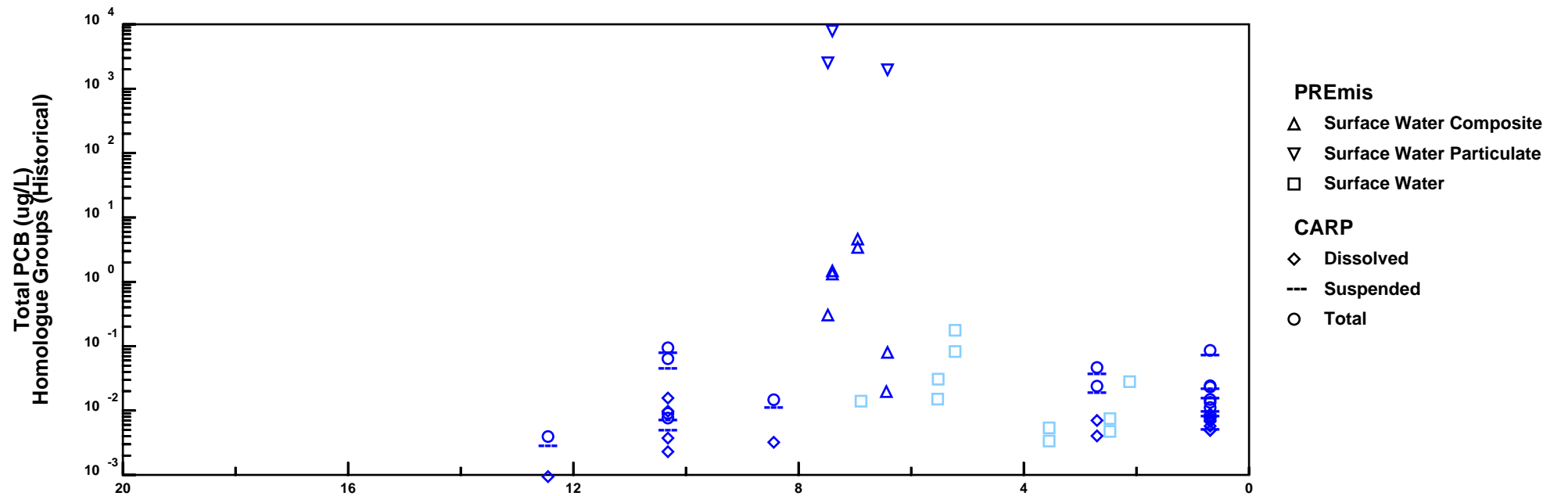
Passaic River

Total DDT (ug/L)

Mile From Confluence of the Passaic River with Newark Bay

PREmis
△ Surface Water Composite
▽ Surface Water Particulate
□ Surface Water

CARP
◇ Dissolved
--- Suspended
○ Total

Time Periods (color code):
■ 1990-1991
■ 1992-1993
■ 1994-1995
■ 1996-1997
■ 1998-2000

Passaic River

Passaic River

Passaic River

Total PAH (ug/L)

Mile From Confluence of the Passaic River with Newark Bay

PREmis

△ Surface Water Composite

▽ Surface Water Particulate

□ Surface Water

CARP

◇ Dissolved

--- Suspended

○ Total

Time Periods (color code):

■ 1990-1991
■ 1992-1993
■ 1994-1995
■ 1996-1997
■ 1998-2000
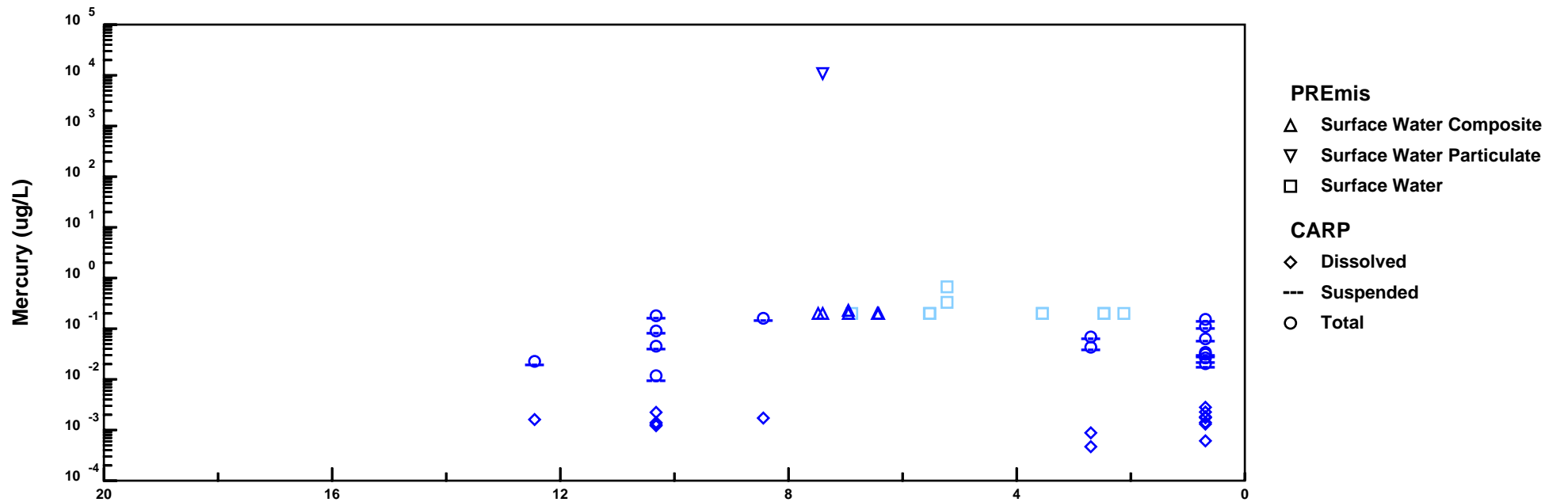
Project/CARP SEDIMENT PLOTS
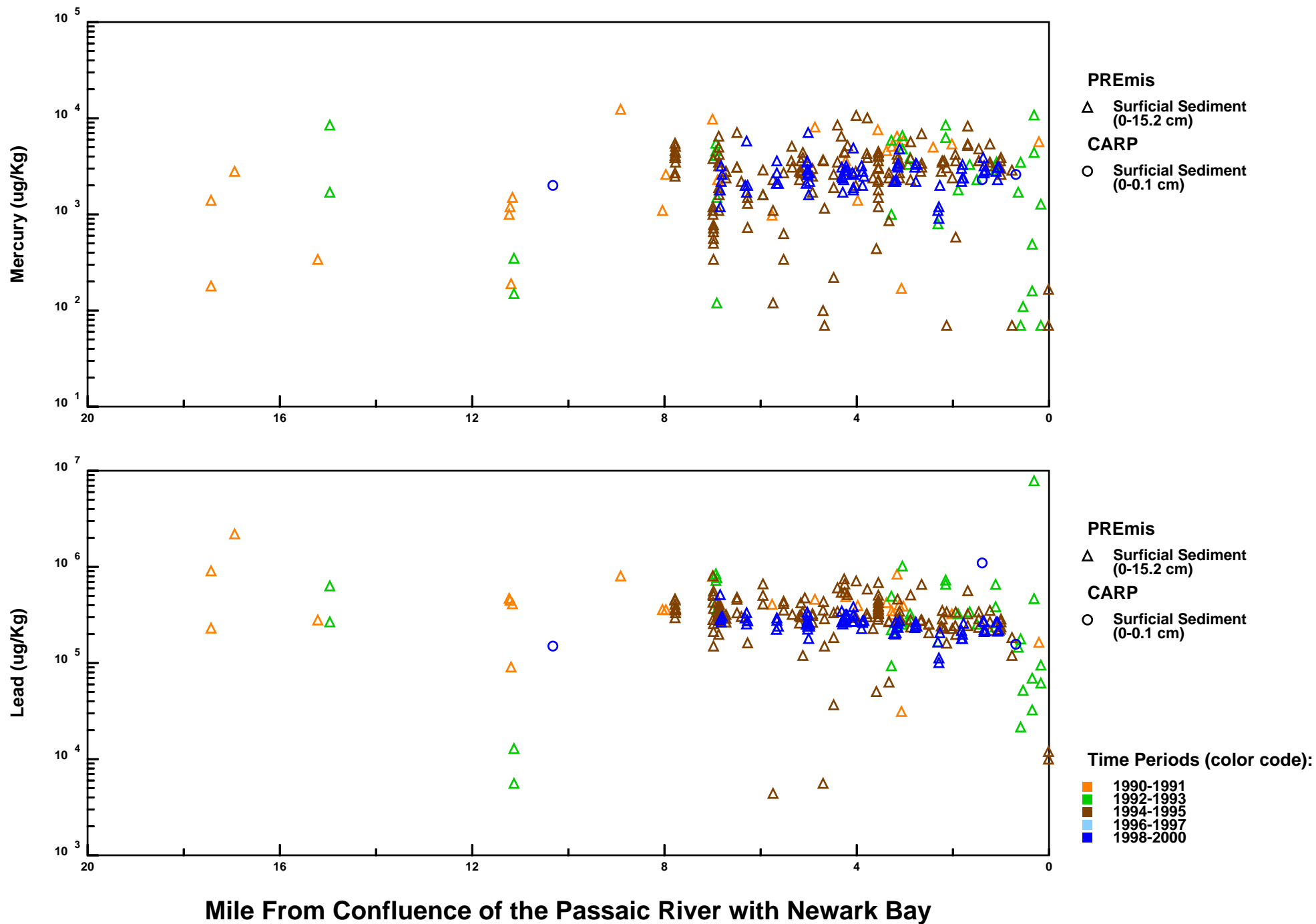
Passaic River

Passaic River
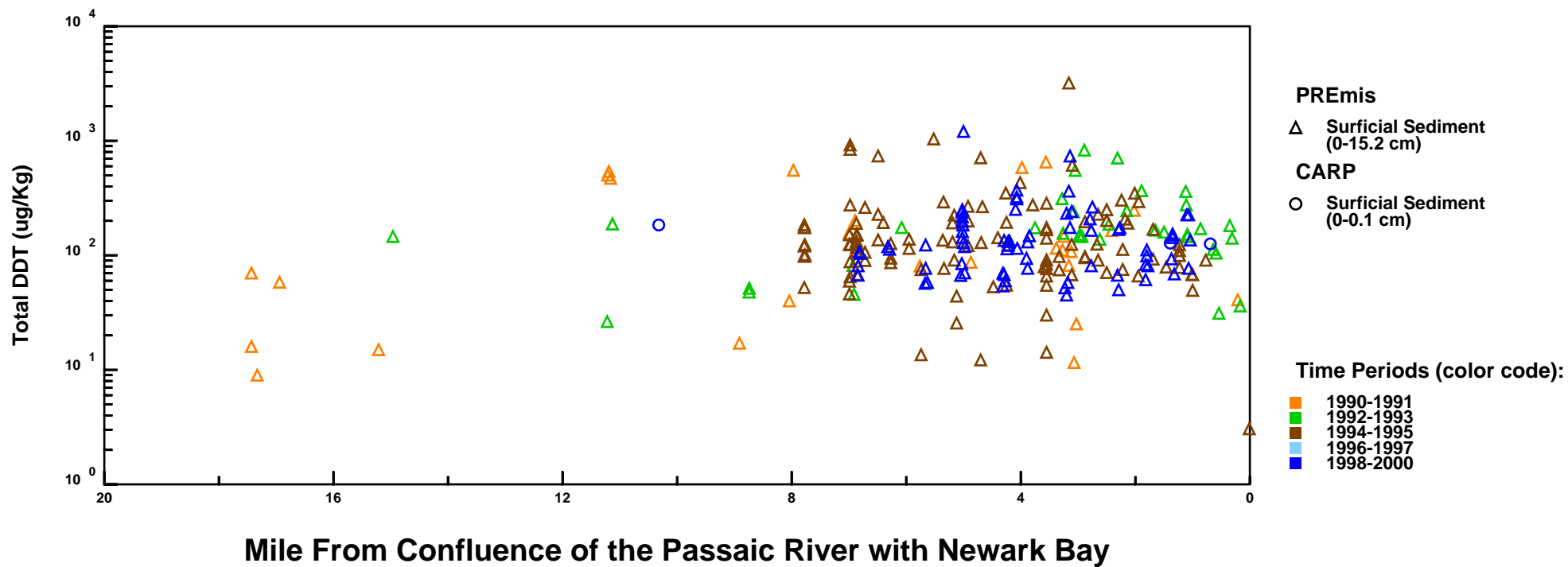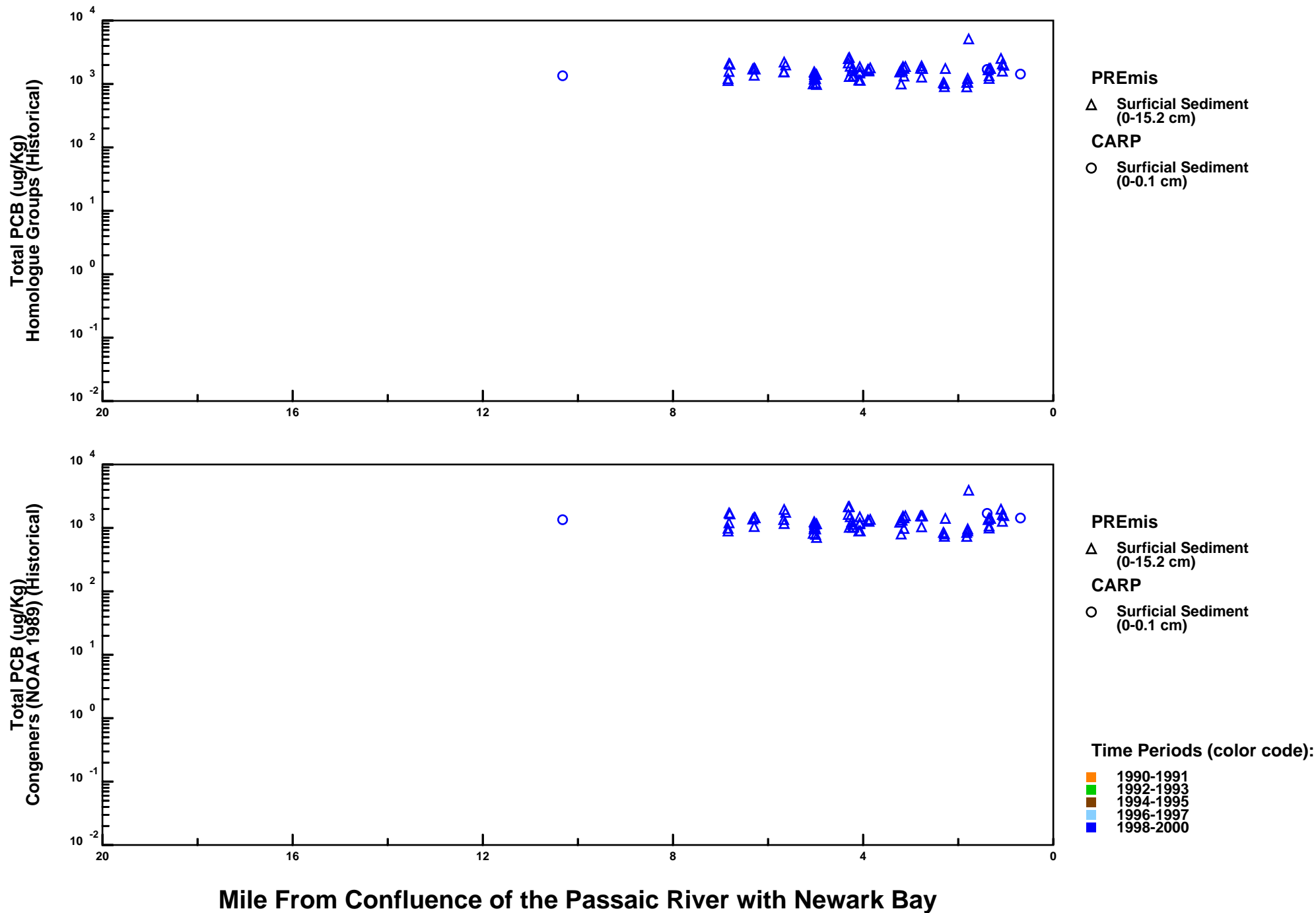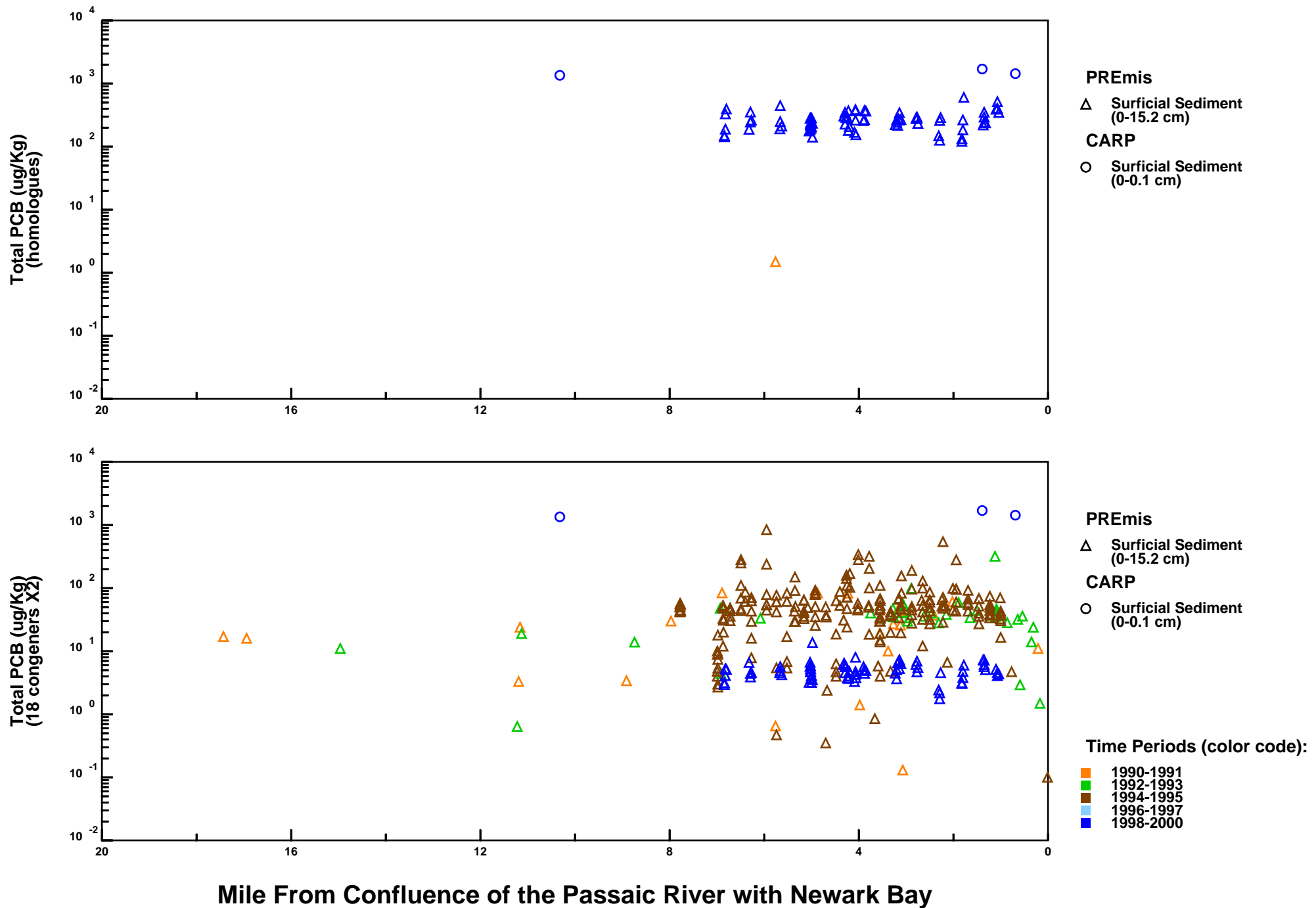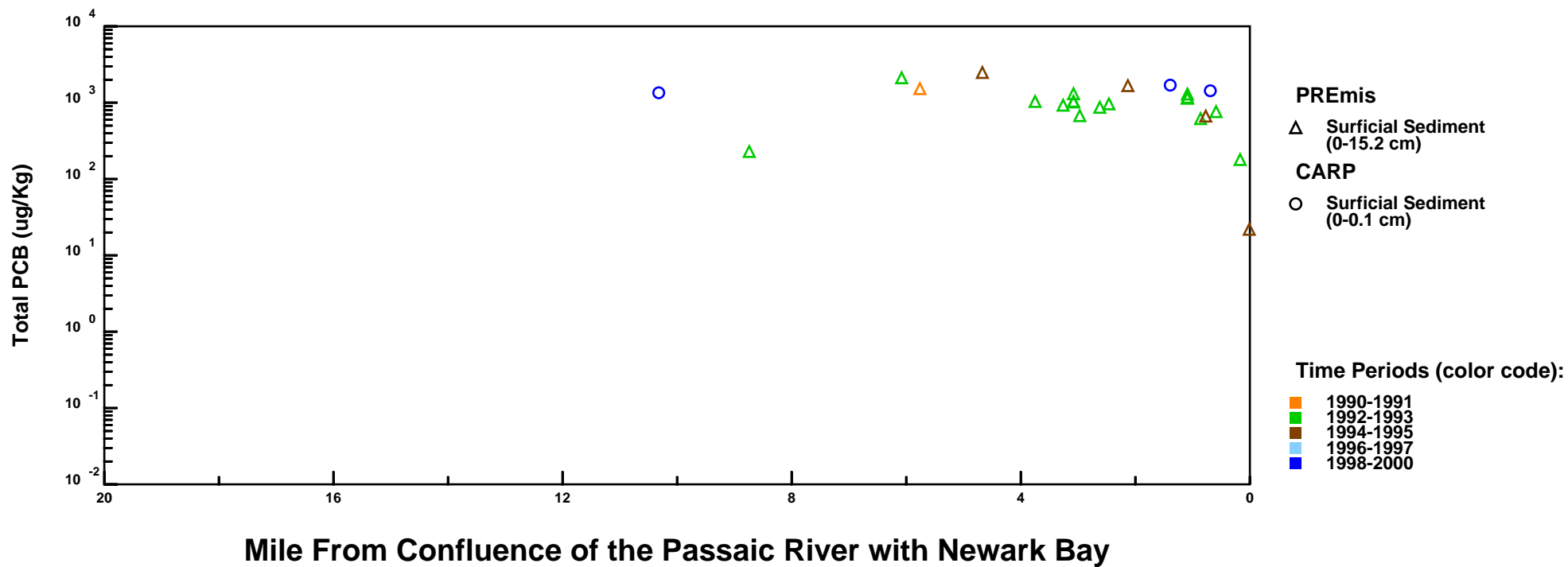
Passaic River

Passaic River

Passaic River

Total PCB (ug/Kg) vs **Mile From Confluence of the Passaic River with Newark Bay**

PREmis

△ Surficial Sediment (0-15.2 cm)

CARP

○ Surficial Sediment (0-0.1 cm)

Time Periods (color code):
- 1990-1991
- 1992-1993
- 1994-1995
- 1996-1997
- 1998-2000
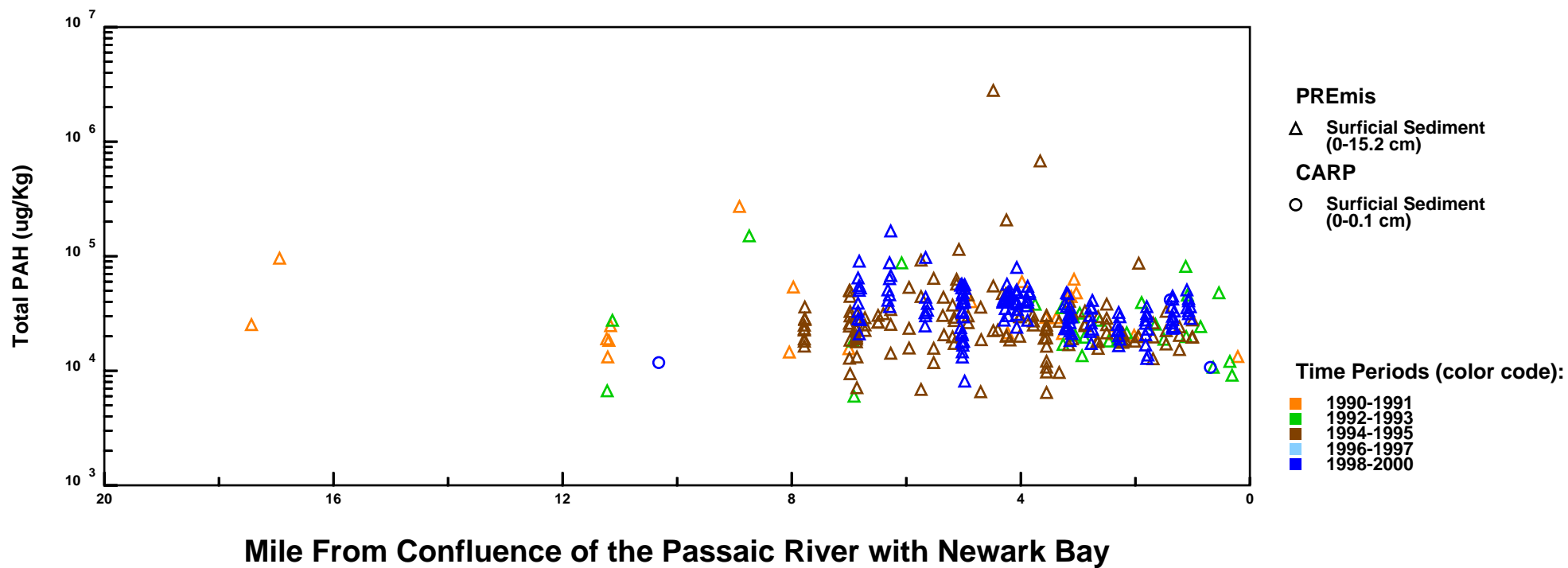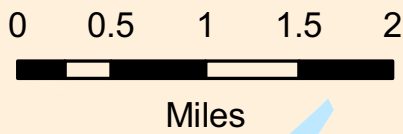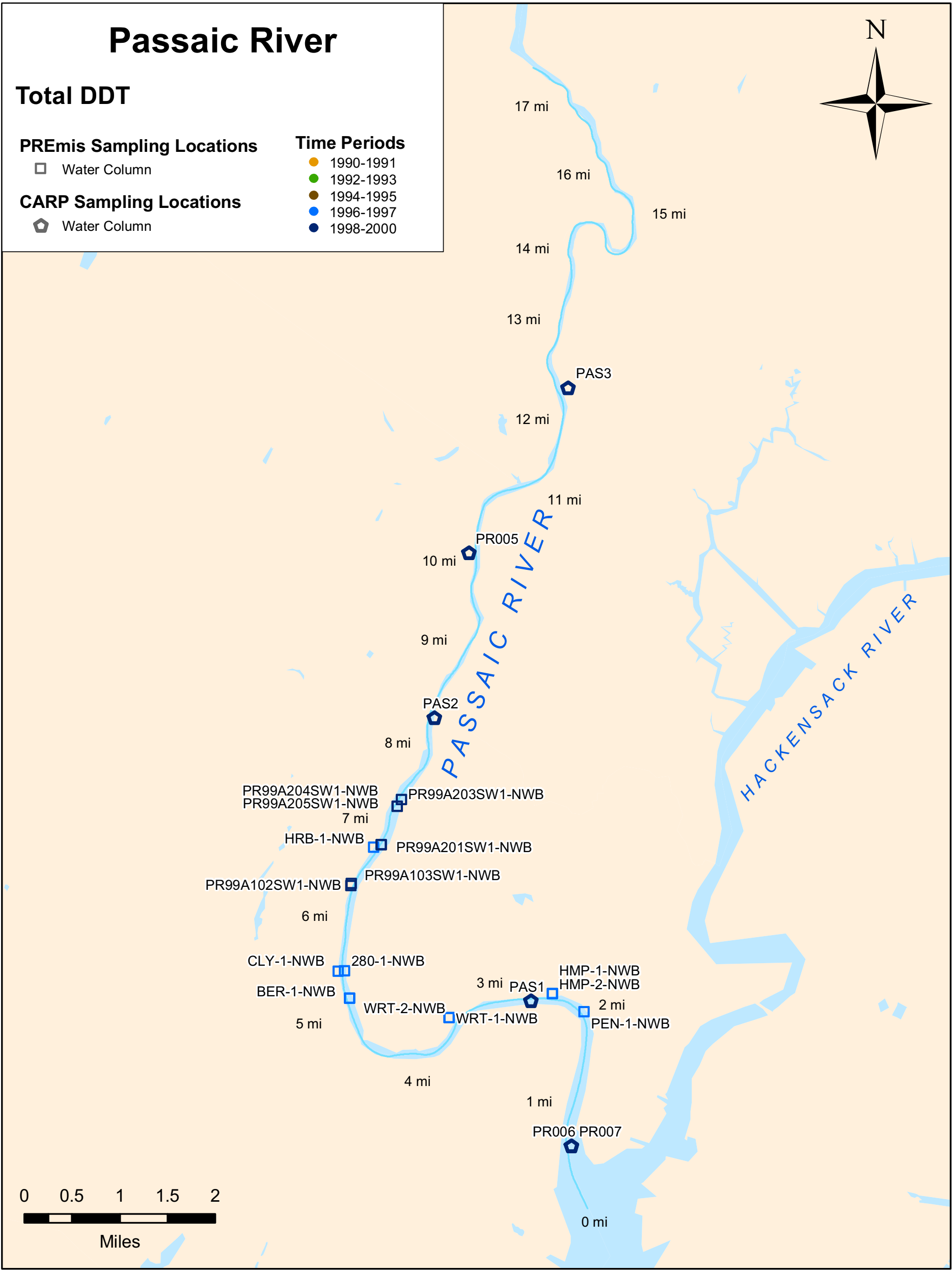
Passaic River
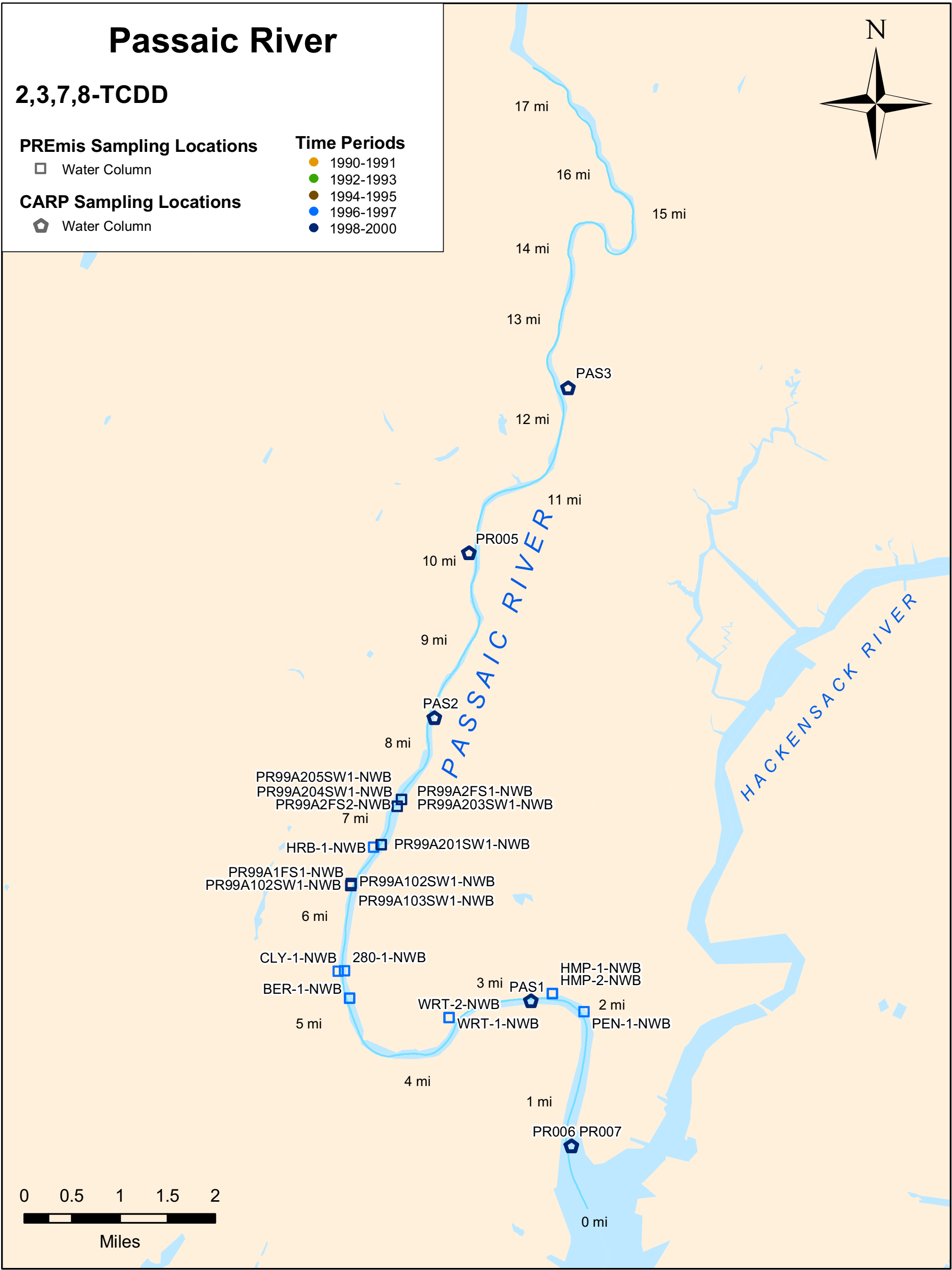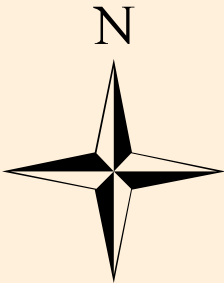
Passaic River

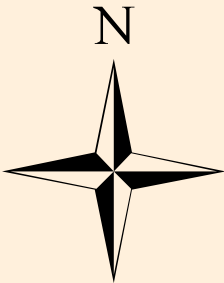# Passaic River

Total tetra-CDD

PREmis Sampling Locations
☐ Water Column

CARP Sampling Locations
⬠ Water Column

Time Periods
● 1990-1991
● 1992-1993
● 1994-1995
● 1996-1997
● 1998-2000

N

17 mi
16 mi
15 mi
14 mi
13 mi
PAS3
12 mi
11 mi
PR005
10 mi
9 mi
PAS2
8 mi
PR99A205SW1-NWB
PR99A204SW1-NWB
PR99A2FS2-NWB   PR99A2FS1-NWB
PR99A203SW1-NWB
7 mi
PR99A201SW1-NWB
HRB-1-NWB
PR99A102SW1-NWB   PR99A102SW1-NWB
PR99A1FS1-NWB
6 mi
CLY-1-NWB   280-1-NWB
BER-1-NWB
3 mi   PAS1   HMP-1-NWB
WRT-2-NWB   2 mi
5 mi   WRT-1-NWB   PEN-1-NWB
4 mi
1 mi
PR006 PR007
0 mi

PASSAIC RIVER

HACKENSACK RIVER

0 0.5 1 1.5 2
Miles
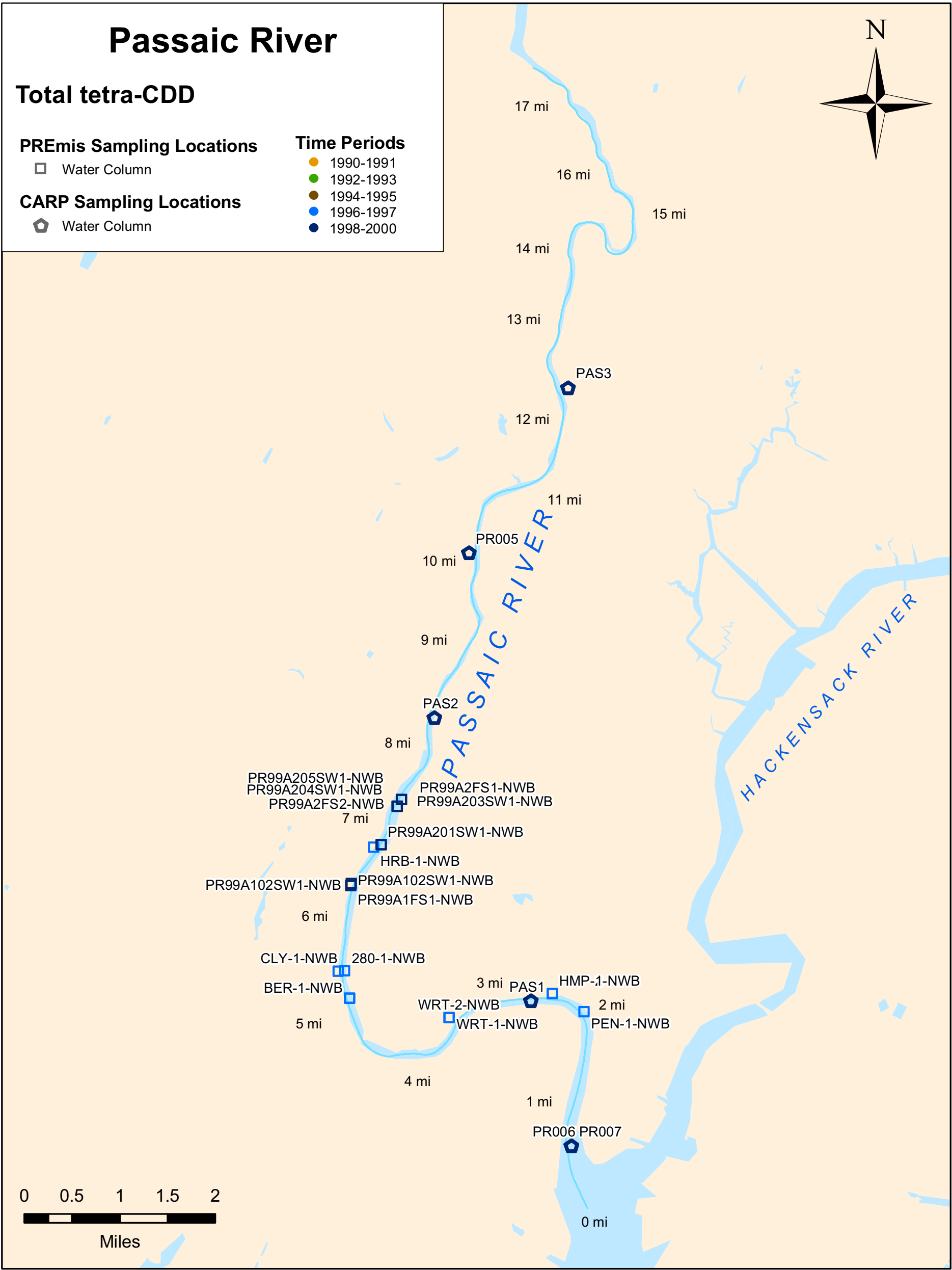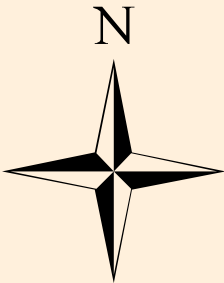
Passaic River

Total PAH

PREmis Sampling Locations
☐ Water Column

CARP Sampling Locations
⬠ Water Column

Time Periods
● 1990-1991
● 1992-1993
● 1994-1995
● 1996-1997
● 1998-2000

N

17 mi
16 mi
15 mi
14 mi
13 mi
PAS3
12 mi
11 mi
PR005
10 mi
9 mi
PAS2
8 mi

PASSAIC RIVER

PR99A205SW1-NWB
PR99A204SW1-NWB
PR99A2FS2-NWB
PR99A203SW1-NWB
7 mi
PR99A201SW1-NWB
PR99A102SW1-NWB
PR99A103SW1-NWB
6 mi

5 mi
3 mi
PAS1
2 mi
4 mi
1 mi
PR006 PR007
0 mi

HACKENSACK RIVER

0   0.5   1   1.5   2
Miles
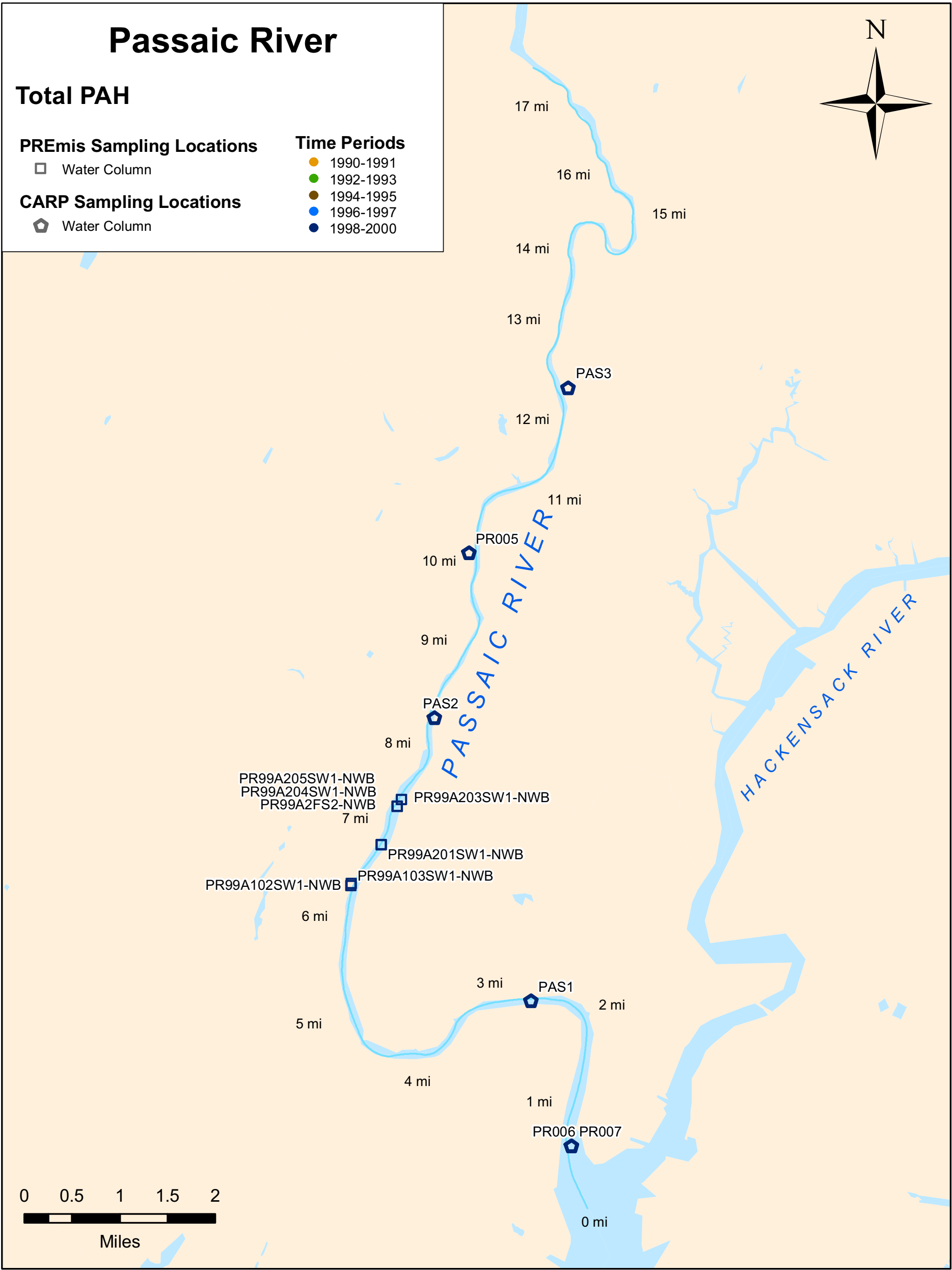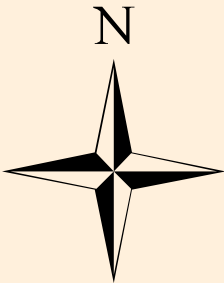
Passaic River

Total PCB

PREmis Sampling Locations
☐ Water Column

CARP Sampling Locations
⬠ Water Column

Time Periods
● 1990-1991
● 1992-1993
● 1994-1995
● 1996-1997
● 1998-2000

N

17 mi

16 mi

15 mi

14 mi

13 mi

PAS3

12 mi

11 mi

PR005

10 mi

9 mi

PASSAIC RIVER

HACKENSACK RIVER

PAS2

8 mi

PR99A2FS2-NWB
PR99A205SW1-NWB
PR99A204SW1-NWB   PR99A2FS1-NWB
                   PR99A203SW1-NWB

7 mi

HRB-1-NWB   PR99A201SW1-NWB

PR99A1FS1-NWB
PR99A102SW1-NWB   PR99A103SW1-NWB

6 mi

280-1-NWB   HMP-1-NWB
CLY-1-NWB   HMP-2-NWB
          BER-1-NWB   3 mi
                       WRT-1-NWB   2 mi
5 mi   PAS1   PEN-1-NWB
          WRT-2-NWB

4 mi

1 mi

PR006 PR007

0 mi

0   0.5   1   1.5   2
Miles
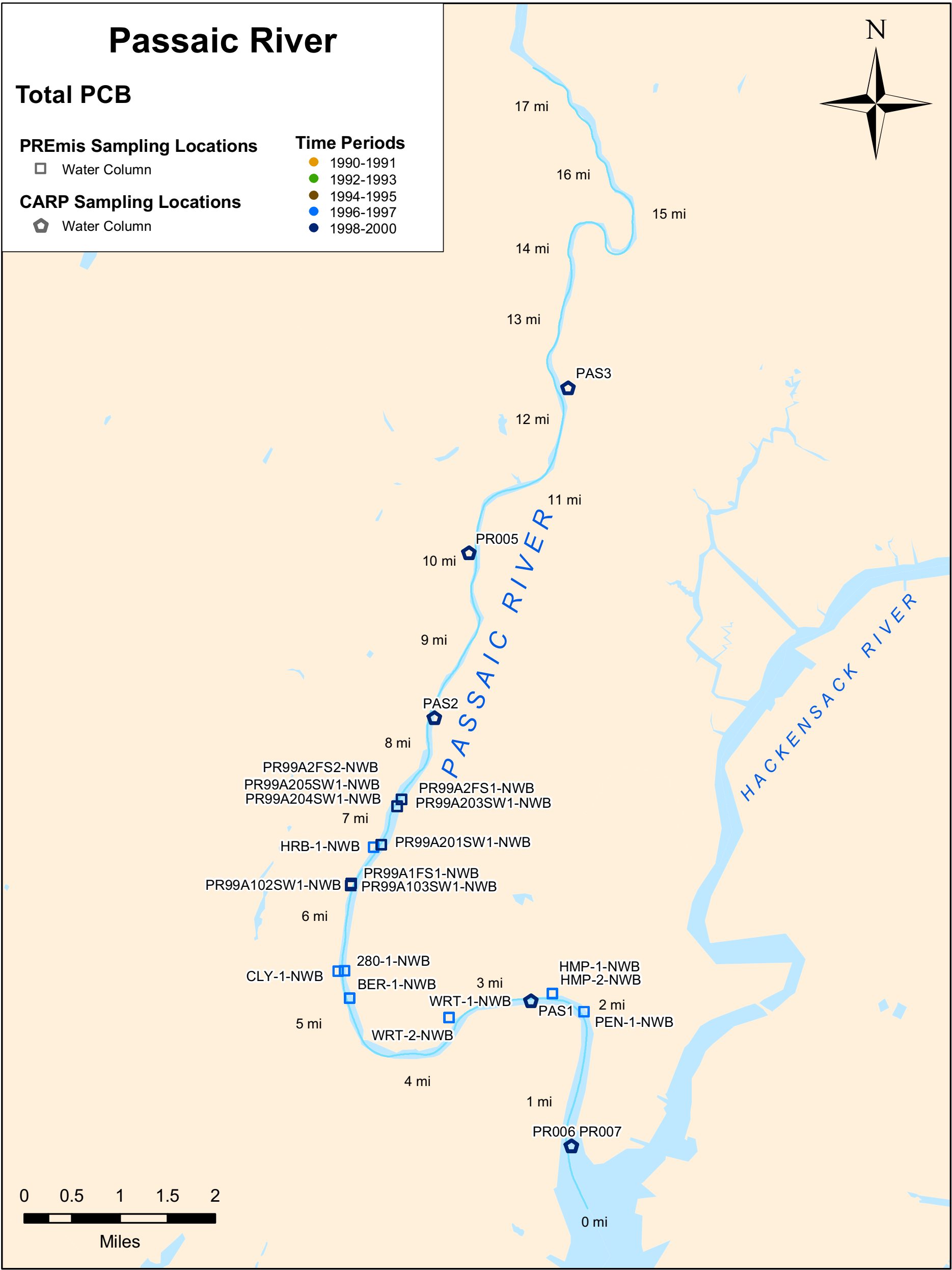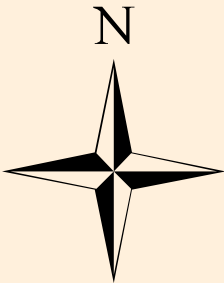
Passaic River

Mercury
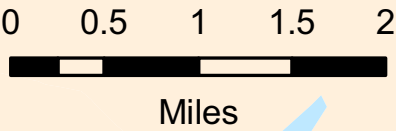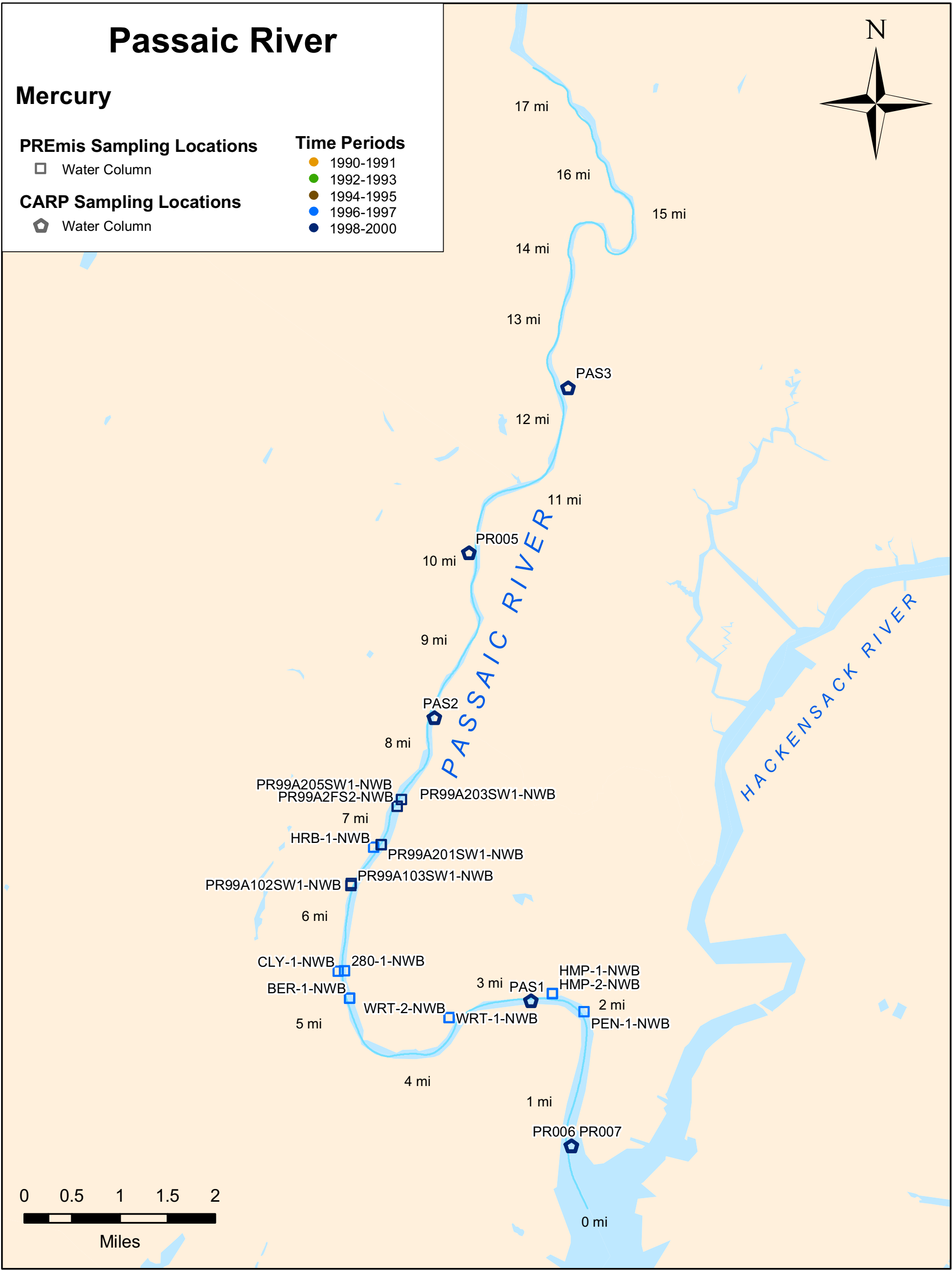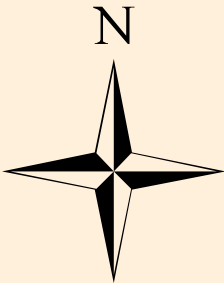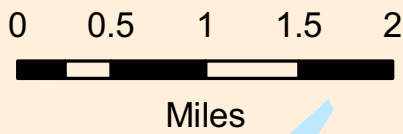
PREmis Sampling Locations
☐ Water Column

CARP Sampling Locations
⬠ Water Column

Time Periods
- 🟠 1990-1991
- 🟢 1992-1993
- 🟤 1994-1995
- 🔵 1996-1997
- 🔵 1998-2000

N

17 mi
16 mi
15 mi
14 mi
13 mi

PAS3
12 mi
11 mi

PR005
10 mi

9 mi

PAS2
8 mi

PR99A205SW1-NWB
PR99A2FS2-NWB
PR99A203SW1-NWB
7 mi
HRB-1-NWB
PR99A201SW1-NWB
PR99A102SW1-NWB
PR99A103SW1-NWB
6 mi

CLY-1-NWB   280-1-NWB
BER-1-NWB
WRT-2-NWB
5 mi
WRT-1-NWB

3 mi PAS1
HMP-1-NWB
HMP-2-NWB
2 mi
PEN-1-NWB

4 mi

1 mi

PR006 PR007

0 mi

PASSAIC RIVER

HACKENSACK RIVER

0   0.5   1   1.5   2

Miles
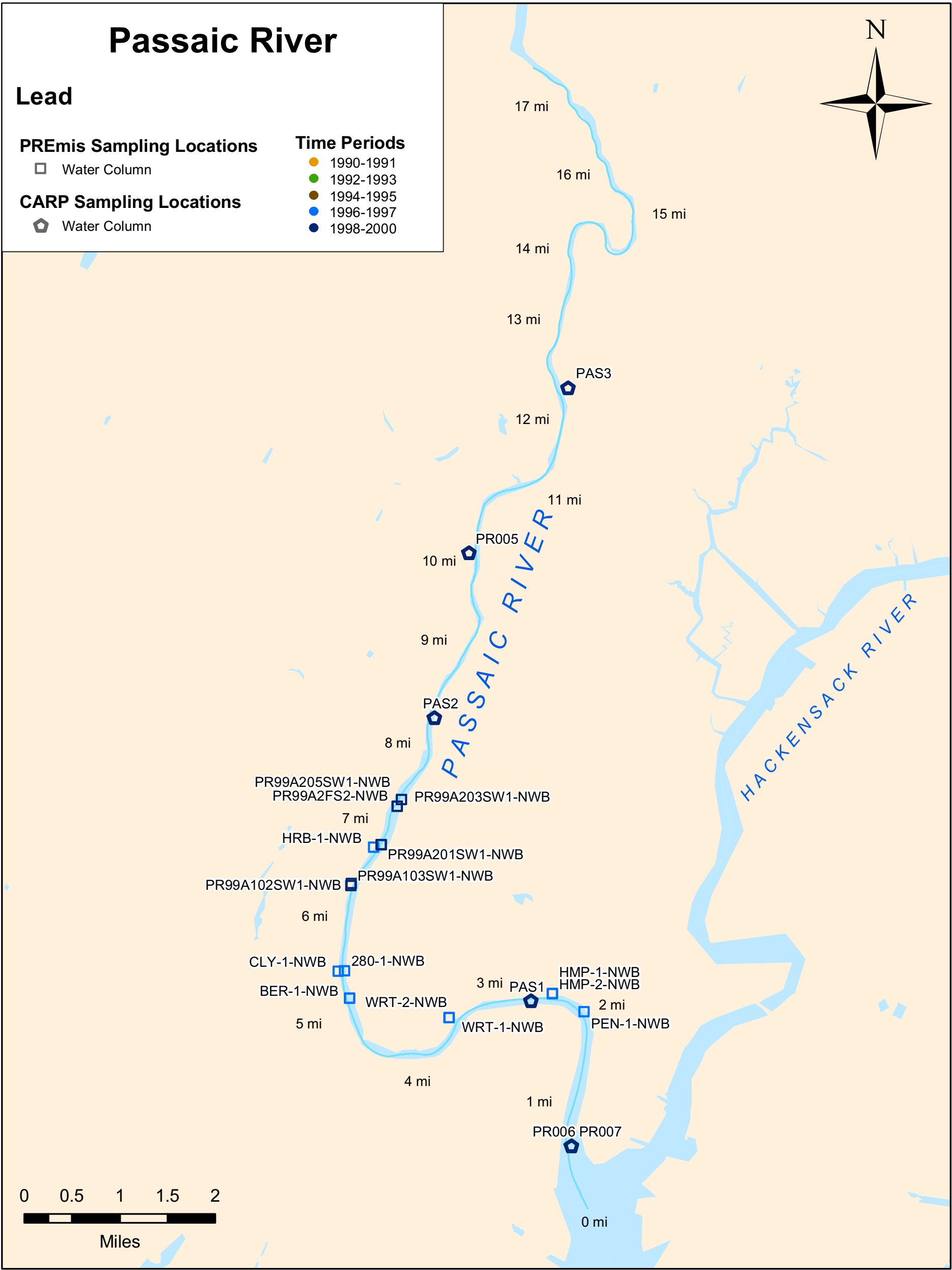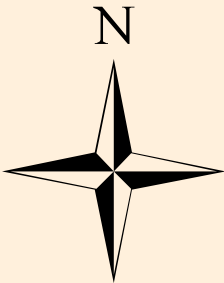
Appendix D:

Battelle Biological Data Compilation

Battelle memorandum dated October 31, 2005 presenting biological data
available from the CARP and project databases for select biological species and
select chemicals.

Battelle

The Business of Innovation

Date	October 31, 2005		Internal Distribution
			E. Barrows
To	Bruce Fidler, Len Warner, AmyMarie Accardi-Dey		T. Gulbransen
	(Malcolm Pirnie)		
From	Greg Durell, Erika Schaub (Battelle)		
Subject	Lower Passaic River Restoration Project: Preparation of Biological Tissue Data Plots		

This memo summarizes Battelle's procedures associated with work conducted as part of WAD 6, Data Management and Presentation, WO 7.3: Preliminary Geochemical and Statistical Analyses, for the Lower Passaic River Restoration Project. Specifically, this subtask was conducted to generate a series of plots illustrating concentrations of selected contaminants in tissue samples collected from the Passaic River. This subtask was a component of Malcolm Pirnie's Historical Data Evaluation and Geochemical Evaluation task.

TASK DESCRIPTION AND SCOPE SUMMARY

A Task Plan was developed by Battelle specifically for this task, based on the original May 2005 Statement of Work and discussions with Malcolm Pirnie. The Task Plan was revised following discussions between Malcolm Pirnie and Battelle. The last revision of the Task Plan, which describes the Scope of Work in detail, was dated 10/17/2005.

The following is a brief summary of the Scope of Work for this task. In this biological data review and plotting exercise, the following chemicals were examined:

- Total DDT (the sum of 4,4′-DDT, 4,4′-DDD, and 4,4′-DDE)
- 2,3,7,8-TCDD
- Ratio of 2,3,7,8-TCDD to Total Tetra-CDD
- Total PAH (as the sum of the 16 USEPA priority pollutant PAH)
- Total PCB (as the sum of all 18 NOAA congeners multiplied by 2, or the sum of Aroclors)
- Total Mercury
- Ratio of Methyl Mercury to Total Mercury
- Total Lead

Using data files available on PREmis and Passaic river tissue data from the CARP database, Battelle compiled the historical biological data and prepared three sets of plots:

- Deliverable I. Scatter Plots showing the concentration of biological tissue concentration versus river mile. Species of interest were Blue Crab, Mummichog, and White Perch.

- Deliverable II. Scatter plot of the ratio of the lipid-normalized biological tissue concentration and the TOC-normalized surficial sediment concentration versus river mile. Species of interest were Blue Crab, Mummichog, and White Perch.

- Deliverable III. Scatter plot showing the tissue contaminant concentrations from laboratory sediment bioaccumulation tests the using laboratory organisms *Macoma nasuta* and *Nereis virens*.

APPROACH

All of the deliverables were plotted using Microsoft Excel. Separate plots were generated for each of the three species, and the tissue concentrations for each parameter were plotted versus actual river mile. The intent was to plot data from the entire 17 mile Passaic River study area. However, there were only data from the lower 7 miles for the species and parameters of interest.

The data for deliverable plots I and II were grouped into four time periods; 1992-1993, 1994-1995, 1998-1999, and 2000-2005 and illustrated on the same plot. No data were available from 1990-1991, or 1996-1997 for the species and parameters of interest. Each year range was plotted using its own symbol and color. Bioaccumulation data were only available for 1993 for sediments collected in the Passaic River, and therefore data for deliverable III were plotted by species (*Macoma nasuta* and *Nereis virens).*

River miles were assigned to each station using a rivermile file obtained from Malcolm Pirnie, Inc., which had station location information, and the centerline01mileseg.shp file obtained through the PREmis website, which also had river mile information. Samples were then plotted by river mile in ArcInfo to ensure that they were assigned an appropriate river mile. The location of two stations, BCH1 and BCH2, were changed as per a letter from TSI dated 08/24/2005. The location of some of the CARP stations were also adjusted as per information obtained from NOAA. One blue crab station (40.74416,-74.13033) was not identified to be moved but it was within 200 feet of a fish station identified to be moved. Since the blue crab station did not originally map inside of a water body and the neighboring fish station was moved to a location inside of the Passaic River, both the blue crab and fish stations were moved to the same location, 40.74749, -74.1294.

To obtain data for the three different deliverable types, river mile information for those stations which were in the Passaic River was added to the original PREmis table, dbo_viewSampleDownloadTable, and those stations not in the study area were removed from the table. Any Passaic River data from the Newark Bay TSI study were also removed from the analysis because they were replicates of samples already in the dataset under a different study name. For ease of plotting the data, river mile stations were rounded to 0.1 mile. All parameters with a concentration/value reported as non-detect, or with a qualifier of U, were reassigned a value of zero.

A query was performed in Microsoft Access for each parameter of interest; a new table was created for each parameter. The query was performed using the column Param_Code. Table 1 identifies each parameter and the code(s) used in the query.

The next step was to sum the individual parameter results for the following: DDT, PAH, NOAA_Congeners, and PCB_Aroclor. This was performed by summing all values having the same entries in the analysis_id column to ensure that data from the same sample were used (e.g., all -1's were summed, all -2's were summed, etc.). The summations were performed in MS Access after retrieving the data from PREmis. Total DDT was calculated by summing the concentrations of the 4,4'-isomers of DDT, DDD, and DDE. Total PAH was calculated by summing the concentrations of the 16 priority pollutant PAH. PCB data reported as NOAA_Congener values were converted to Total PCB by summing the concentrations of the 18 NOAA congeners and multiplying by 2, and PCB data reported as PCB_Aroclor were converted to Total PCB by summing the concentrations of the reported Aroclors. It was noted that the original PREmis data did not always include all parameters used for the summation (i.e., there was not always data for all 16 PAH). The reason why all parameters were sometimes not included in PREmis was not investigated, and the summations were based on the available parameters.

The tissue data was identified by the values in the Matrix_Code column. Table 2 lists which matrix codes used to identify the tissue data for this activity.

Table 1. All of the Parameter Codes Identified to Query the PREmis and CARP Data

Parameter	Param_Code
2,3,7,8_TCDD	"1746-01-6"
DDT	"72-54-8" Or "72-55-9" Or "50-29-3"
Lead	"7439-92-1"
Lipids	"LIPIDS"
Mercury	"7439-97-6"
MethylMercury	"22967-92-6"
NOAA_Congeners	"31508-00-6" Or "35693-99-3" Or "38380-07-3" Or "35065-30-6" Or "35065-29-3" Or "32598-10-0" Or "40186-72-9" Or "32598-14-4" Or "37680-73-2" Or "37680-65-2" Or "35065-28-2" Or "35065-27-1" Or "34883-43-7" Or "7012-37-5" Or "2051-24-3" Or "52663-68-0" Or "52663-78-2" Or "41464-39-5"
PAH	"53-70-3" Or "120-12-7" Or "91-20-3" Or "56-55-3" Or "208-96-8" Or "218-01-9" Or "83-32-9" Or "205-99-2" Or "120-12-7" Or "207-08-9" Or "86-73-7" Or "50-32-8" Or "206-44-0" Or "191-24-2" Or "85-01-8" Or "193-39-5" Or "129-00-0" Or "53-70-3"
PCB_Aroclor	"11097-69-1" Or "12674-11-2" Or "11096-82-5" Or "53469-21-9" Or "12672-29-6" Or "11104-28-2" Or "11141-16-5"
Total_TCDD	"TOT_41903-57-5" Or "41903-57-5"
TOC	"TOC"

Table 2. Matrix Codes and Matrix Type for Tissue Data

Matrix	Matrix_Code
anterior half standard fillet	AHF
Carcass	CARC
whole fish	CW
dorsal fin steak	DFS
Hepatopancreas	HEP
head and viscera removed	HV
Muscle	MSCL
fillet without skin	NOSKFL
remnant carcass	RC
right fillet	RF
standard fillet	SF
fillet and liver composited	SF+LV
soft tissue	SOF
steak scute 2 (anterior)	SS2
steak scute 6 (posterior)	SS6
Tissue	TISSUE
whole fish	WH
whole fish with no liver	WH-LV
whole bodies composited	WHLBD

Per request, fish tissue data from different tissue types were plotted in the same figures because each study had different methodology and tissue samples were reported differently in PREmis (e.g., whole fish, carcass, and fillet and liver composite are all plotted together). The species code was included in the query by linking the information in the dbo_Samples table to the dbo_viewSampleDownloadTable by the Sample_ID column. The following species were of interest for the different plots: Blue Crab (together with those designated as just Crab), Mumichog, White Perch, *Macoma nasuta* and *Nereis virens*. Some of the parameters of interest were to be plotted as ratio values; the sample values of the 2,3,7,8-TCDD to Total TCDD and Methyl Mercury to Total Mercury.

The Blue Crab data and the Fish data in CARP were in a different format, and needed to be queried separately from the PREmis database. The queries were similar in that all non-detects and any with "U" qualifiers were given a value of "0". Units for some of the parameters were not in ng/g and were converted to ng/g. The parameter codes were the same and the appropriate sample values were adjusted in the same manner as described above for the PREmis database.

Sediment data was also identified and placed into a separate table by parameter. This query was performed, again in Microsoft Access, and used the following criteria:

Sample_Type	"Surficial Sediment Grabs"
Depth_Top	0
Depth_Bottom	<0.58

(Assumption- Not all of the records had depth units listed, but most of the units identified were feet, so the assumption was that the records with no depth unit was recorded in feet).

The number of records that were retrieved from the databases and available for plotting can be found in Attachment 1. No data were found from 1990-1991 or 1996-1997 for the species and contaminant parameters of interest. All data points that were plotted are for discrete and separate samples. This may include multiple animals (crab or fish) that were collected at the same time at the same location, but were then analyzed separately.

Deliverables I and III were plotted from the single table outputs provided in Microsoft Access and exported into Microsoft Excel . Deliverable II required additional analyses to produce. Sample data in both the Tissue and Sediment tables were divided by Lipid and TOC results for each sample, respectively. The TOC normalized surface sediment data was averaged for all sediment samples that were collected the same year and within ½ mile of the associated tissue sample. Then Lipid normalized tissue data was then divided by the average TOC normalized sediment data. The plotted normalized results were thus calculated as follows, using the units indicated in numbers 3 through 5 in the list of assumptions below:

$$(([\text{tissue contaminant}] \div [\text{tissue lipid}]) \div ([\text{sediment contaminant}] \div [\text{sediment TOC}]))$$

Assumptions and Other Information for the Plots:

1. It was assumed that the values in the SampleResultPPBValue column in the dbo_viewSampleDownloadTable were in ng/g; these are the concentration data fields that were used for this task.
2. It was assumed that the location information, concentration values, and assumed concentration units obtained from PREmis were accurate; the quality and accuracy of the data in the PREmis database is not fully known and was not further checked for this exercise.

3. It was assumed that the tissue data retrieved from PREmis were all in ng/g wet weight and sediment data were assumed to be in ng/g dry weight. These are the data that have been plotted.
4. It was assumed that the tissue lipid data in PREmis were in percent wet weight, and the results remained as a percent for the data normalization.
5. The TOC data were reported as either percent or ng/g in PREmis, and the values in the percent were assumed to be g/100g. The units of the data reported in ng/g data were converted to g/100g (percent), for consistency, and the results remained as a percent for the data normalization. It was assumed that the TOC data were on a dry weight basis, like the sediment contaminant data.
6. The lipid- and TOC-normalized ratio plots (Deliverable II) were generated based on lipid-normalized tissue data on a wet weigh basis (see #4 above) divided by TOC-normalized sediment data on a dry weight basis (see #5 above), and as indicated with the equation above.
7. Some of the records were missing depth units. Most of the depth units were recorded in feet, therefore it was assumed that all records were recorded in a depth of feet.
8. Samples identified as Crab were assumed to be Blue Crab data, and plotted with the Blue Crab data.

The queries went through a QA/QC procedure developed through Battelle's Quality Assurance Program. The results of the QA/QC procedure can be found in Attachment 2.

Attachment 1
Number of Records Available for Plotting

Year	Species	Number of Field Tissue Samples							
		Total DDT (4,4-DDT/DDD/DDE)	2,3,7,8-TCDD	Total Tetra-CDD	Total PAH	Total PCB	Mercury	Methyl-Mercury	Lead
1990-1991	Blue crab	0	0	0	0	0	0	0	0
	White Perch	0	0	0	0	0	0	0	0
	Mummichog	0	0	0	0	0	0	0	0
1992-1993	Blue crab	2	4	4	0	2	2	0	2
	White Perch	0	0	0	0	0	0	0	0
	Mummichog	0	0	0	0	0	0	0	0
1994-1995	Blue crab	6	6	6	6	12	6	6	6
	White Perch	5	1	1	0	5	5	0	0
	Mummichog	5	5	5	5	15	5	5	5
1996-1997	Blue crab	0	0	0	0	0	0	0	0
	White Perch	0	0	0	0	0	0	0	0
	Mummichog	0	0	0	0	0	0	0	0
1998-1999	Blue crab	65	56	56	113	139	65	0	60
	White Perch	29	21	21	31	51	29	0	9
	Mummichog	51	51	51	100	102	51	0	21
2000-2005	Blue crab	7	7	7	14	14	7	0	7
	White Perch	25	25	25	40	50	35	0	6
	Mummichog	6	6	6	9	13	7	0	4

Year	Number of Field Surface Sediment Samples				Number of Field Surface Sediment Samples with both Contaminant and TOC Data			
	Total DDT (4,4-DDT/DDD/DDE)	2,3,7,8-TCDD	Total PAH	Total PCB	Total DDT (4,4-DDT/DDD/DDE)	2,3,7,8-TCDD	Total PAH	Total PCB
1990-1991	34	30	31	57	25	21	24	25
1992-1993	37	48	36	60	37	48	36	39
1994-1995	139	137	138	357	138	133	138	219
1996-1997	0	0	0	3	0	0	0	0
1998-1999	57	57	114	114	57	57	114	57
2000-2005	17	17	34	34	17	17	34	17

Year	Number of Field Tissue Samples Available for Deliverable II Plots[a]			
	Total DDT (4,4-DDT/DDD/DDE)	2,3,7,8-TCDD	Total PAH	Total PCB
1990-1991	0	0	0	2
1992-1993	2	0	0	0
1994-1995	5	0	0	5
1996-1997	0	0	0	0
1998-1999	27	10	20	67
2000-2005	12	0	0	23

[a] Number of tissue samples with contaminant and lipid data collected in a location where there were also sediment sample(s) with contaminant and TOC data collected within ½ mile of the tissue sample.

| Year | Species | Number of Laboratory Tissue Samples from Bioaccumulation Tests Using Sediments from the Passaic River | | | | | | | |
		Total DDT (4,4-DDT/DDD/DDE)	2,3,7,8-TCDD	Total Tetra-CDD	Total PAH	Total PCB	Mercury	Methyl-Mercury	Lead
1990-1991	*Macoma nasuta*	0	0	0	0	0	0	0	0
	Nereis virens	0	0	0	0	0	0	0	0
1992-1993	*Macoma nasuta*	5	0	0	5	5	5	0	5
	Nereis virens	5	1	0	5	5	5	0	5
1994-1995	*Macoma nasuta*	0	0	0	0	0	0	0	0
	Nereis virens	0	0	0	0	0	0	0	0
1996-1997	*Macoma nasuta*	0	0	0	0	0	0	0	0
	Nereis virens	0	0	0	0	0	0	0	0
1998-1999	*Macoma nasuta*	0	0	0	0	0	0	0	0
	Nereis virens	0	0	0	0	0	0	0	0
2000-2005	*Macoma nasuta*	0	0	0	0	0	0	0	0
	Nereis virens	0	0	0	0	0	0	0	0

Deliverable I

I.1 Total DDT

Total DDT Concentration in Blue Crab Tissue vs River Mile
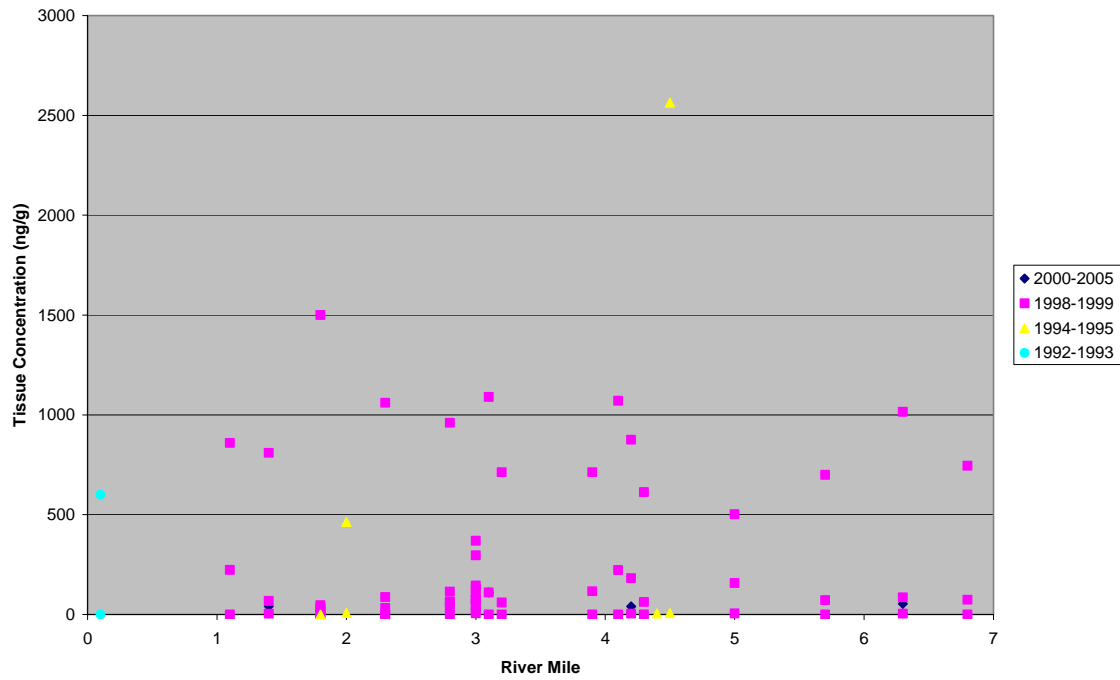
Total DDT Concentration in Mummichog Tissue vs River Mile
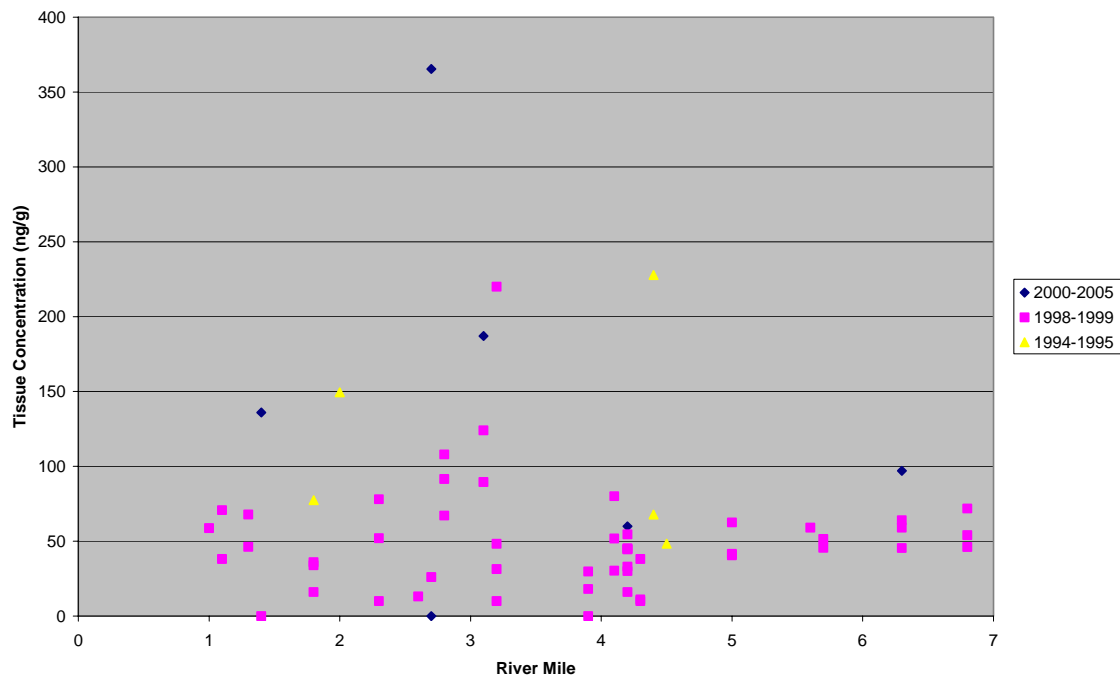
Total DDT Concentraion in White Perch Tissue vs River Mile
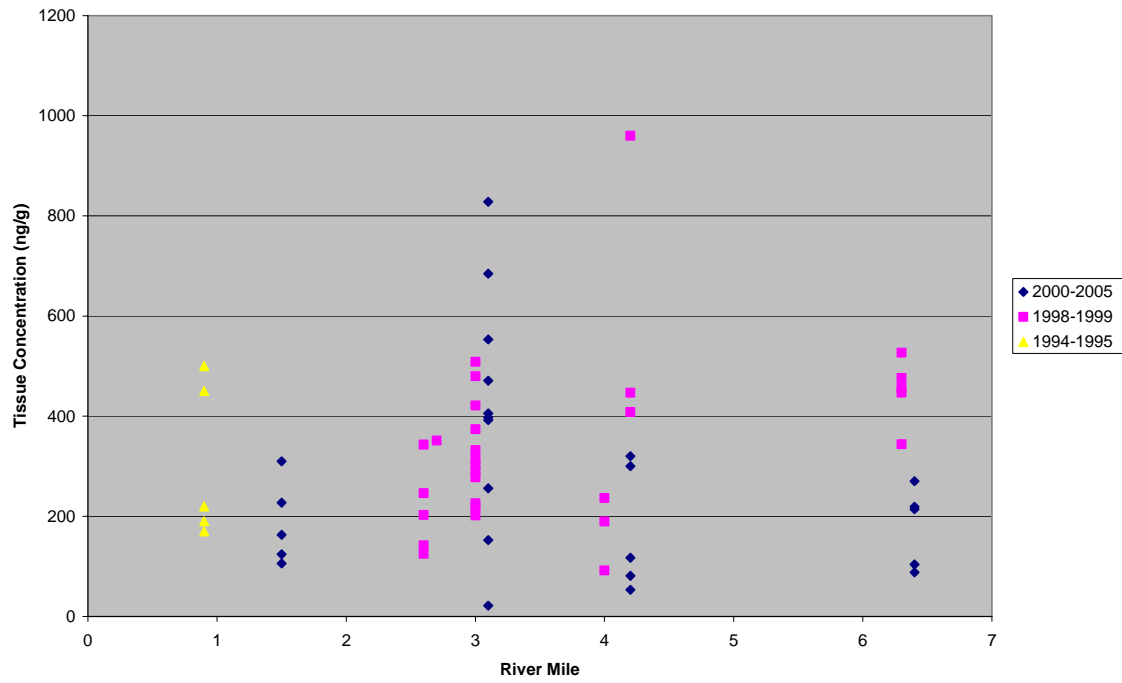
I.2 2,3,7,8-TCDD

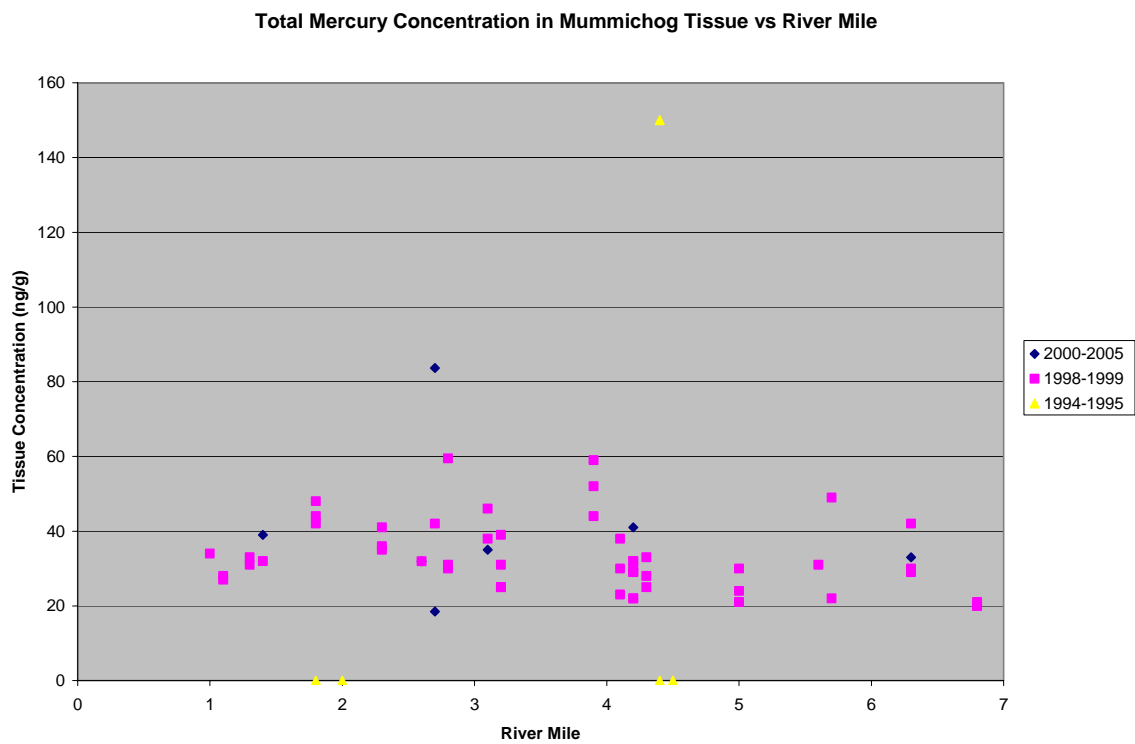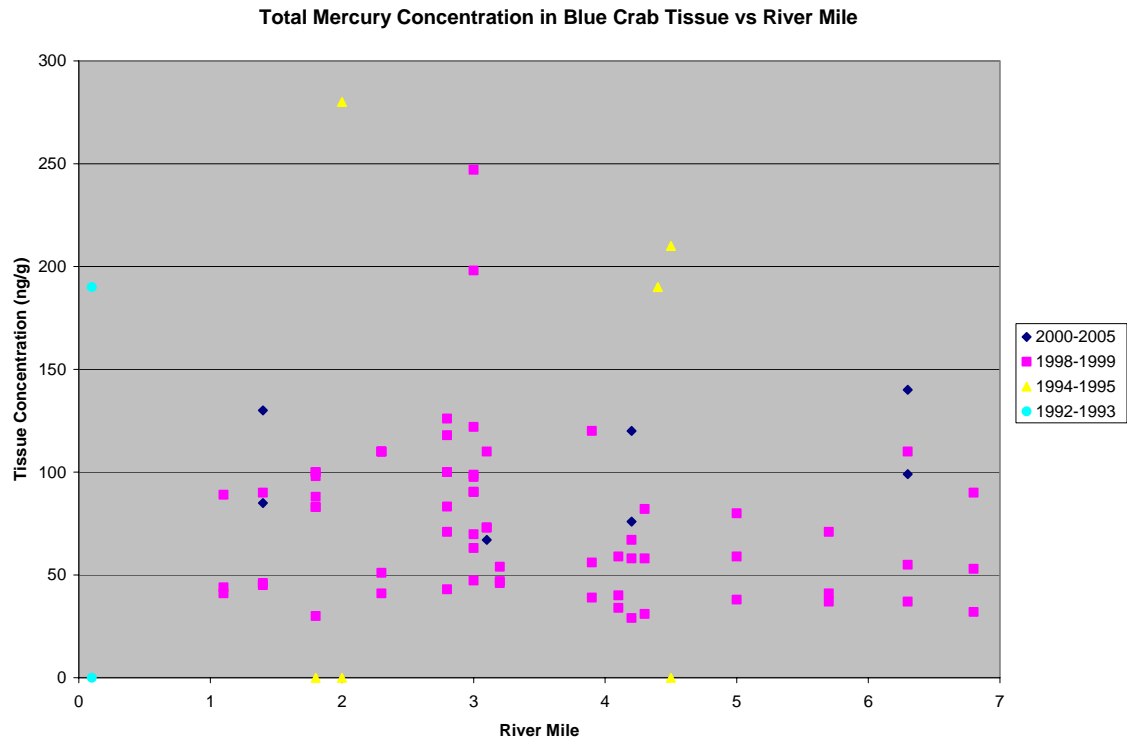**2,3,7,8-TCDD Concentration in Blue Crab Tissue vs River Mile**
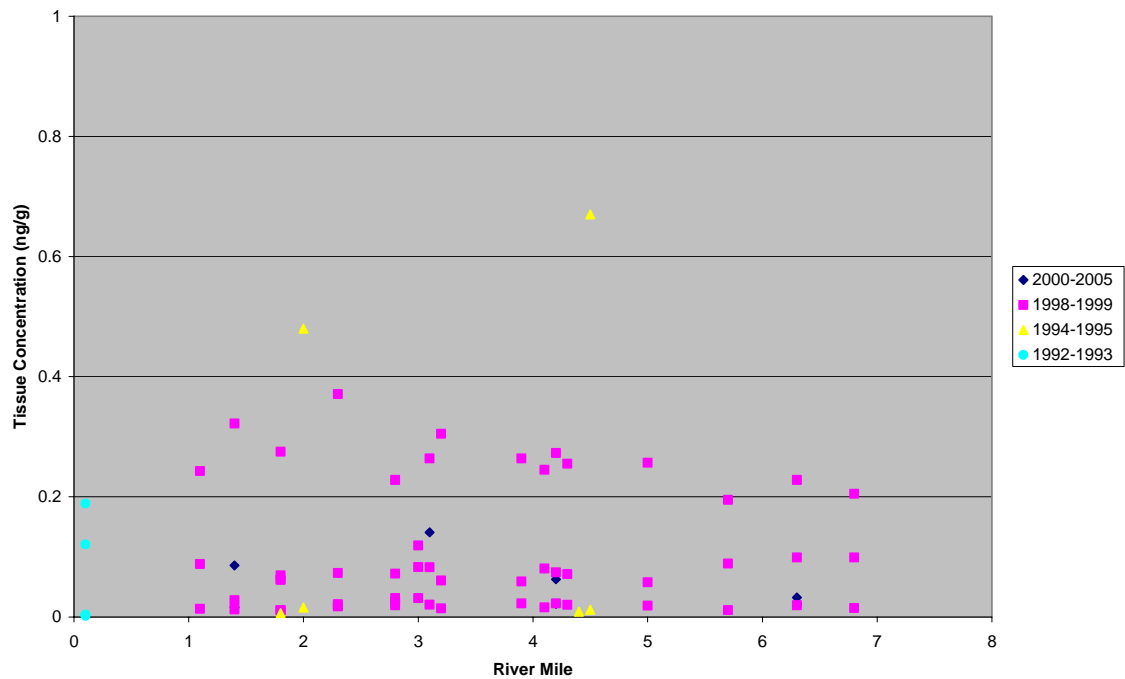
2,3,7,8-TCDD Concentration in Mummichog Tissue vs River Mile
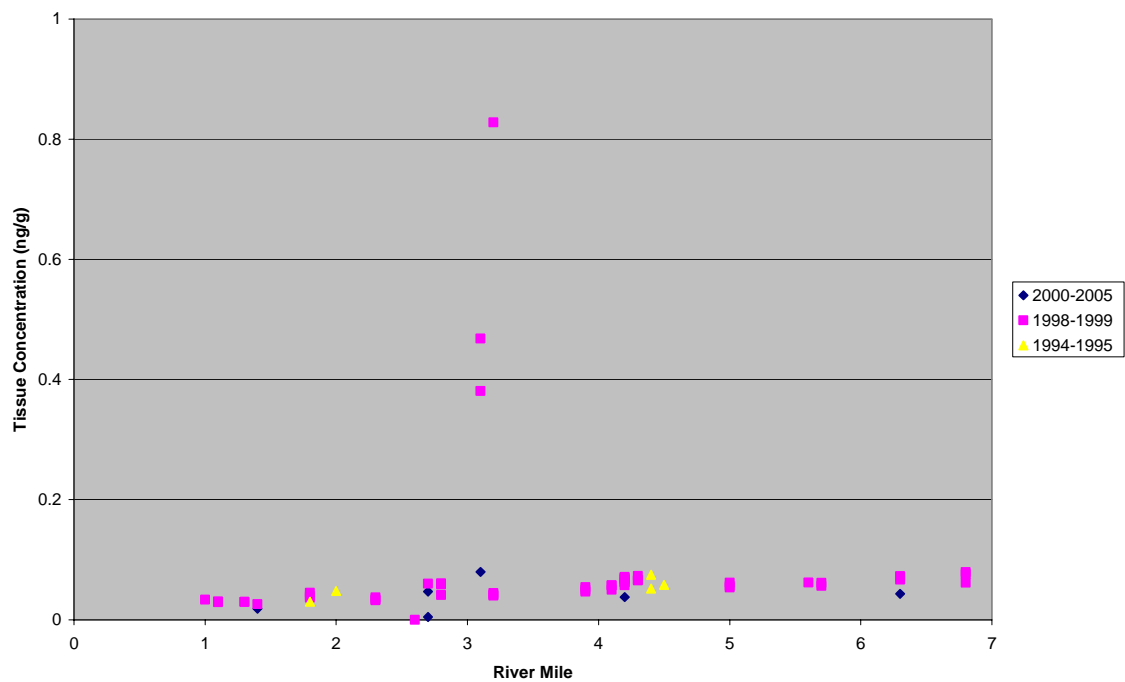
2,3,7,8-TCDD Concentration in White Perch Tissue vs. River Mile
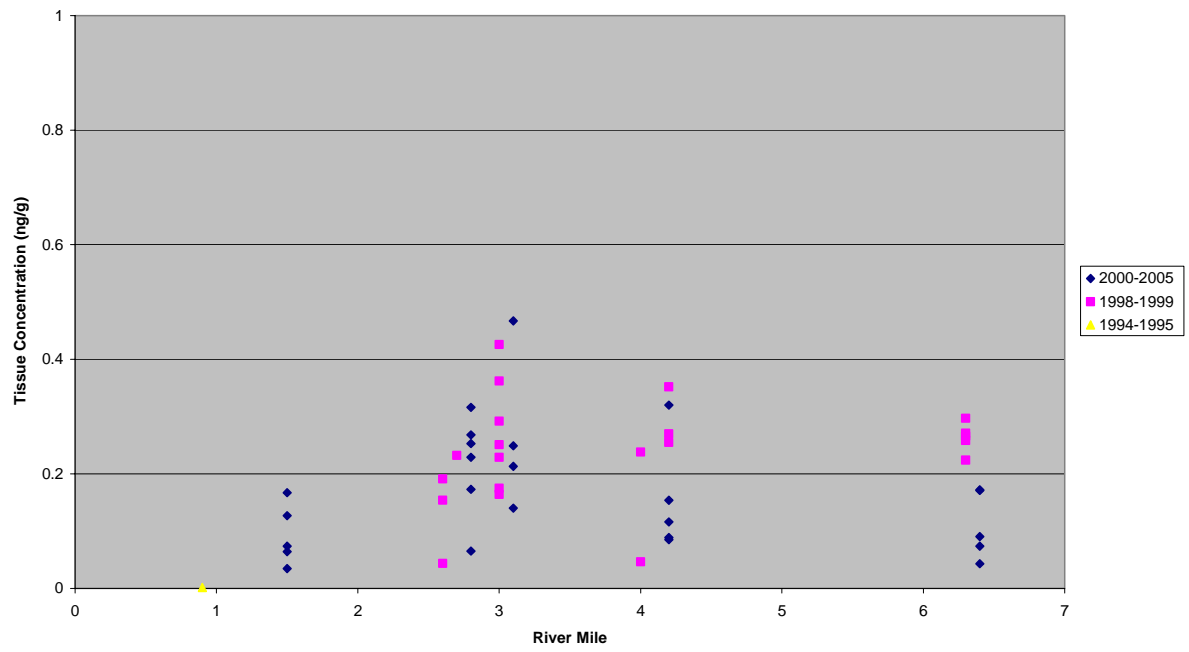
I.3 Ratio of 2,3,7,8-TCDD to Total Tetra-CDD

Ratio of 2,3,7,8-TCDD to Total Tetra-CDD Concentration in Blue Crab Tissue vs River Mile
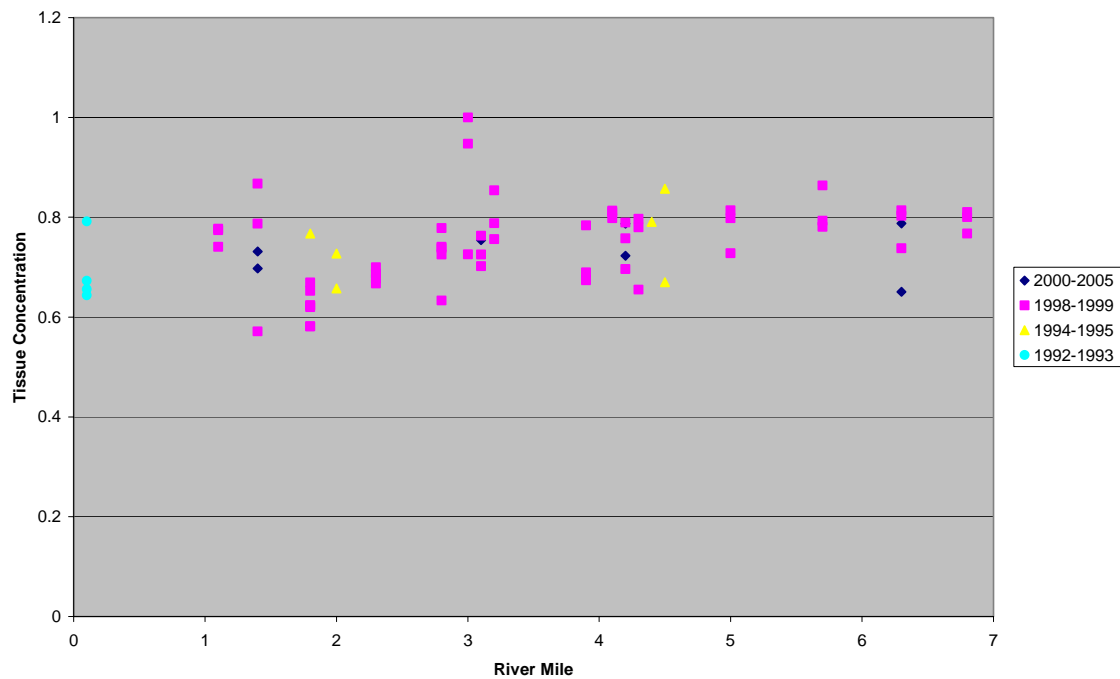
Ratio of 2,3,7,8-TCDD to Total Tetra-CDD Concentration in Mummichog Tissue vs River Mile
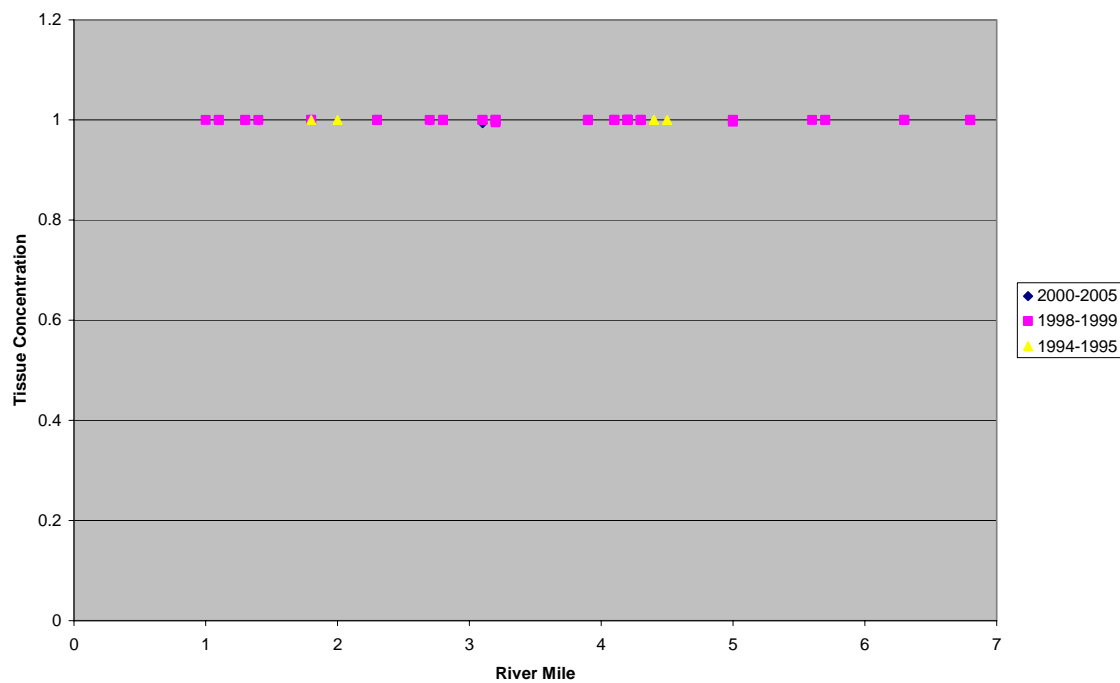
Ratio of 2,3,7,8-TCDD to Total Tetra-CDD Concentration in White Perch Tissue vs River Mile

I.4 Total PAH

Total PAH Concentration in Blue Crab Tissue vs River Mile

Total PAH Concentration in Blue Crab Tissue vs River Mile

(1999, 1.8 miles, 2320 ng/g)
(1999, 2.3 miles, 2320 ng/g)
(1995, 4.5 miles, 1470 ng/g)

REPLICATE BLUE CRAB PLOT, WITH A REDUCED CONCENTRATION SCALE

Total PAH Concentration in Mummichog Tissue vs River Mile
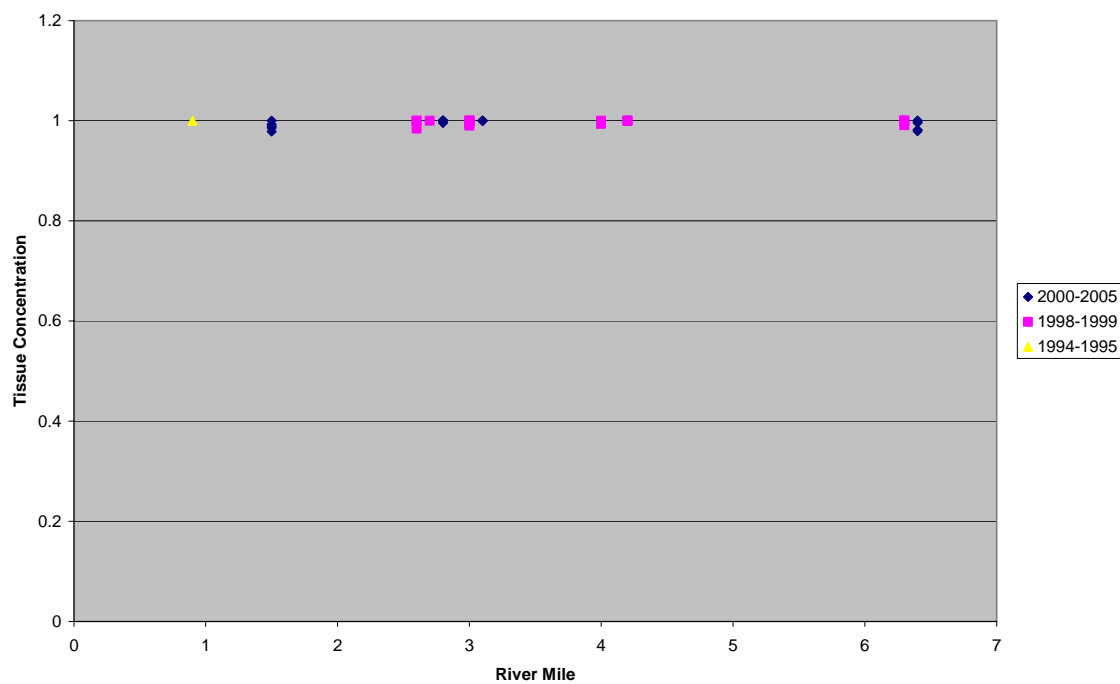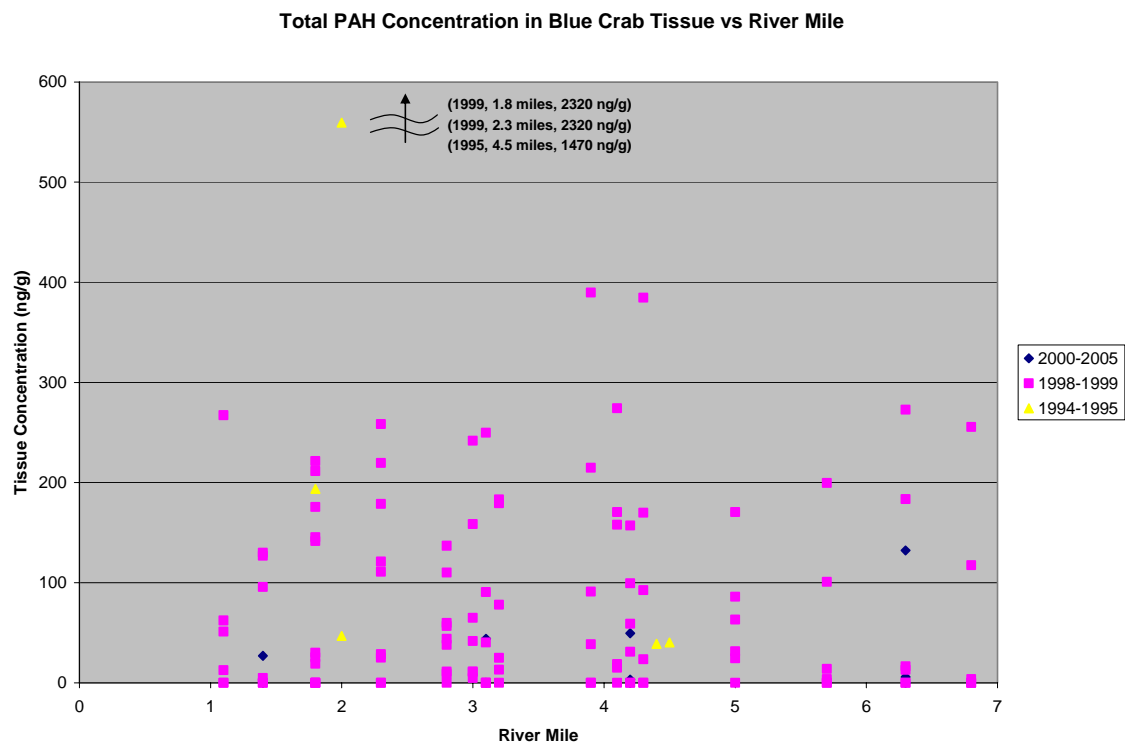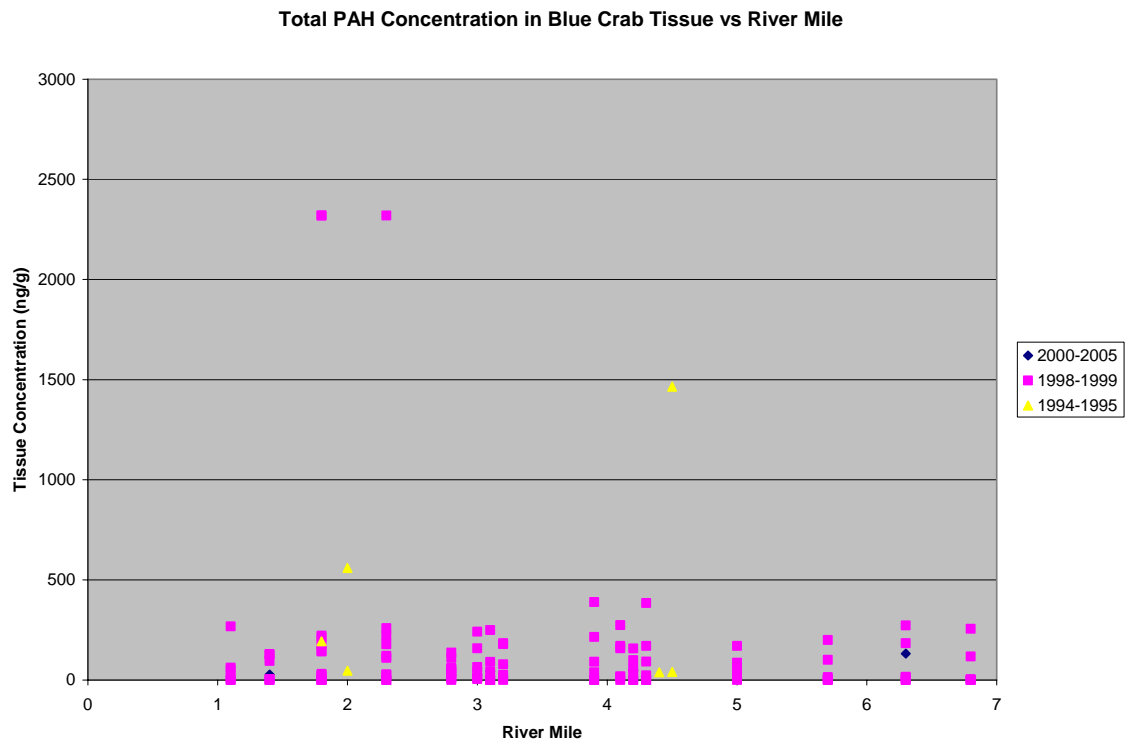
Total PAH Concentration in Mummichog Tissue vs River Mile
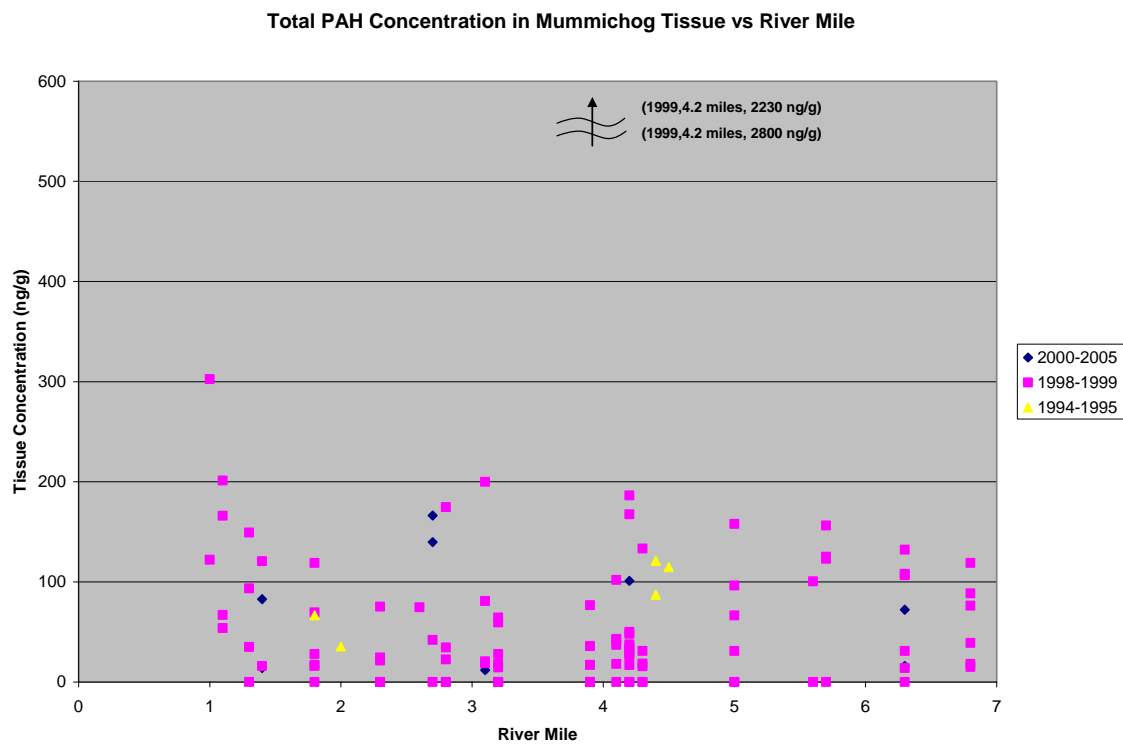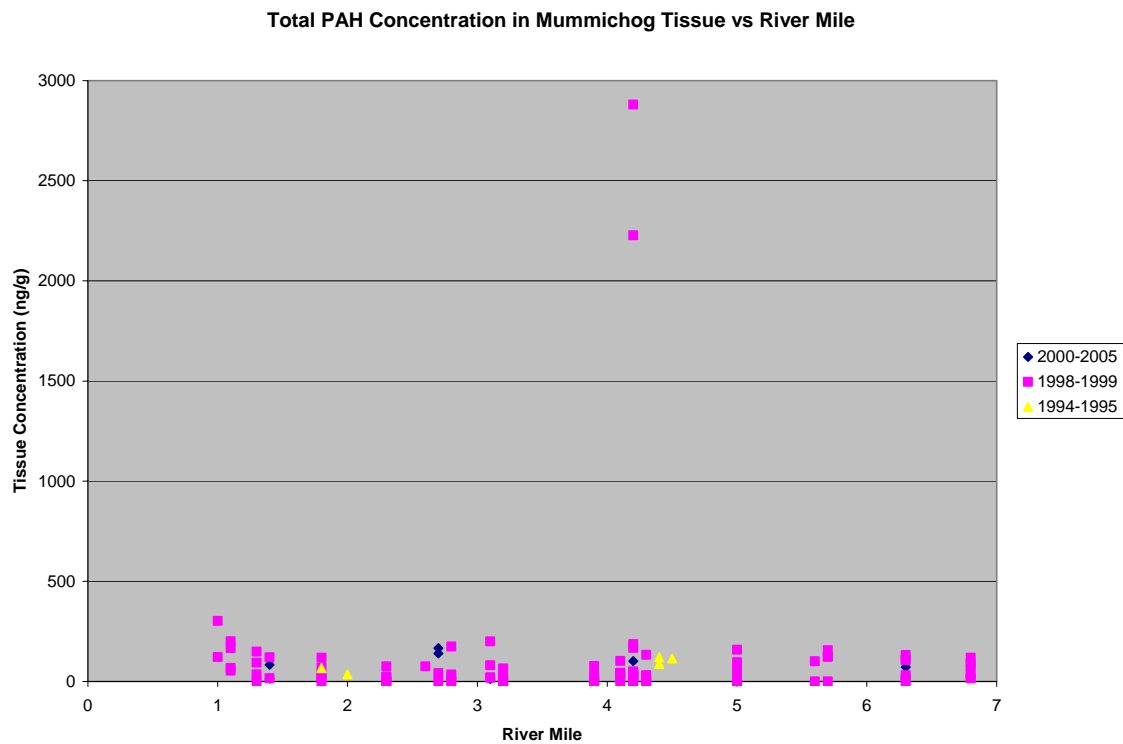
REPLICATE MUMMICHOG PLOT, WITH A REDUCED CONCENTRATION SCALE

8

Total PAH Concentration in White Perch Tissue vs River Mile

I.5 Total PCB

Total PCB Concentration in Blue Crab Tissue vs River Mile

Total PCB Concentration in Blue Crab Tissue vs River Mile

(1999,1.8 miles,101,000 ng/g)
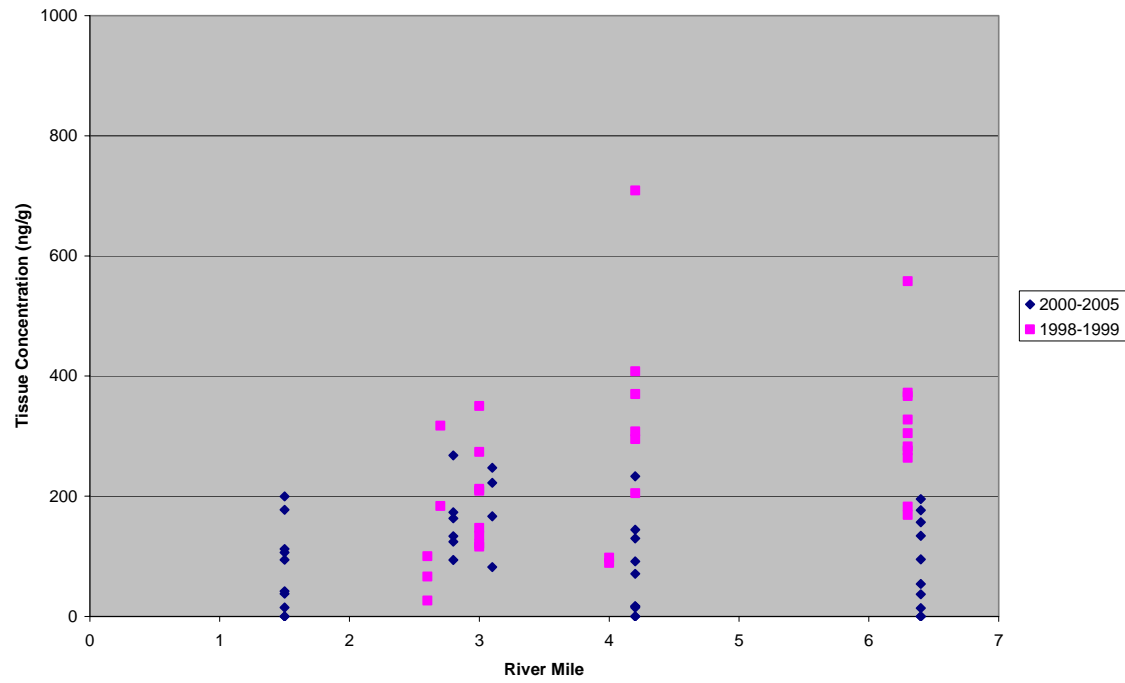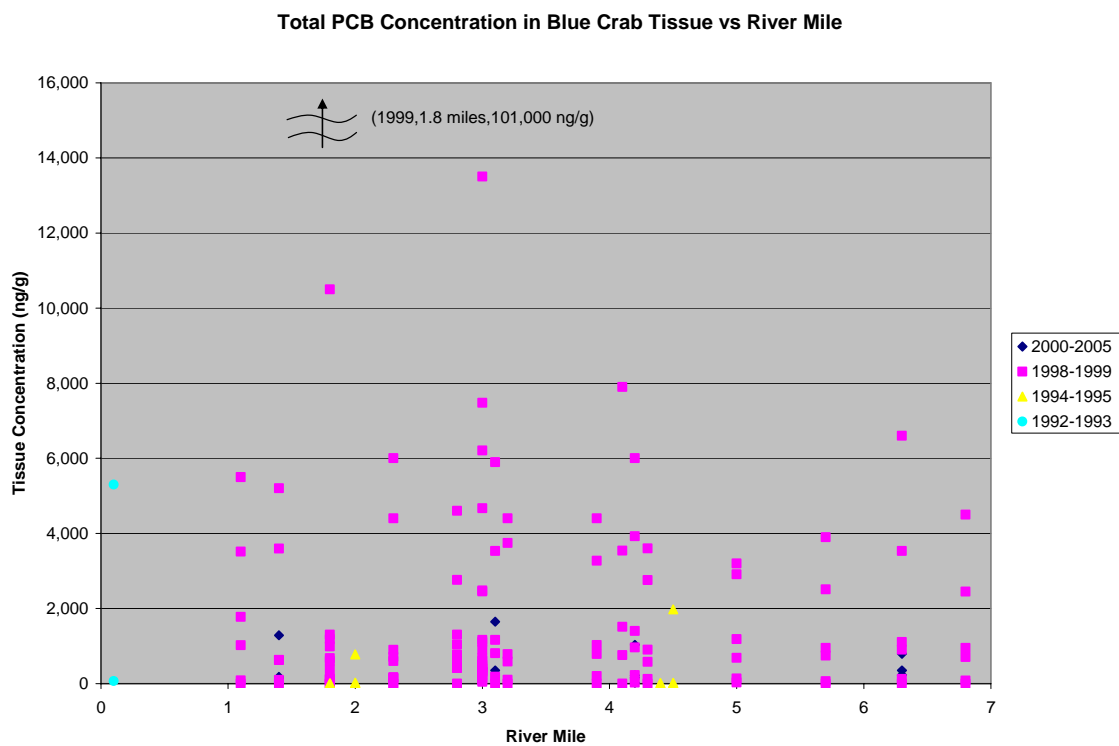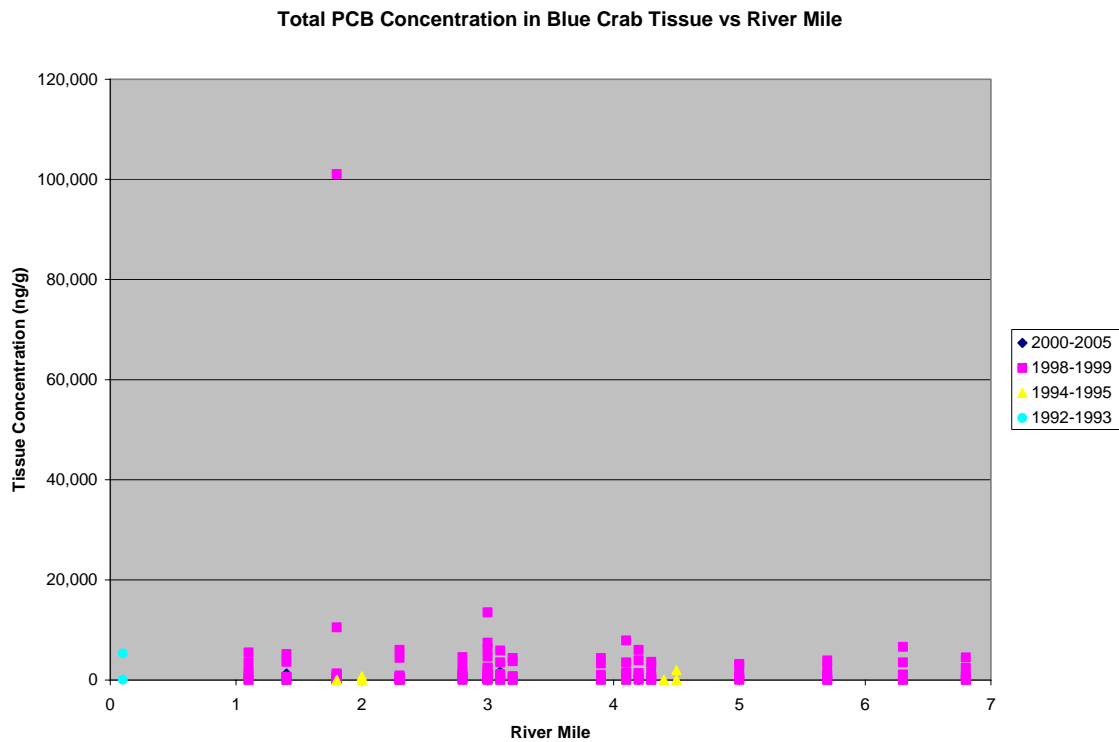
REPLICATE BLUE CRAB PLOT, WITH A REDUCED CONCENTRATION SCALE

Total PCB Concentration in Mummichog Tissue vs River Mile
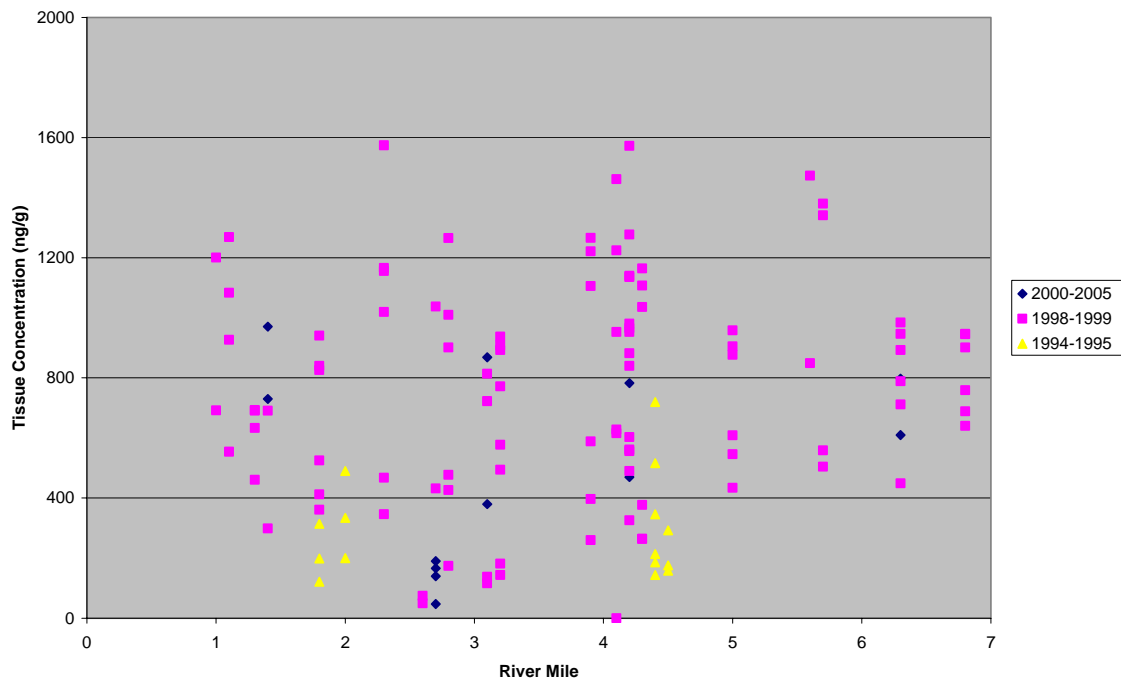
Total PCB Concentration in White Perch Tissue vs River Mile

11

I.6 Total Mercury

Total Mercury Concentration in Blue Crab Tissue vs River Mile

Total Mercury Concentration in Mummichog Tissue vs River Mile

Total Mercury Concentration in White Perch Tissue vs River Mile

I.7 Ratio of Methyl Mercury to Total Mercury

Ratio of Methyl-Mercury to Total Mercury Concentration in Blue Crab Tissue vs River Mile

Ratio of Methyl Mercury to Total Mercury Concentration in Mummichog Tissue vs River Mile
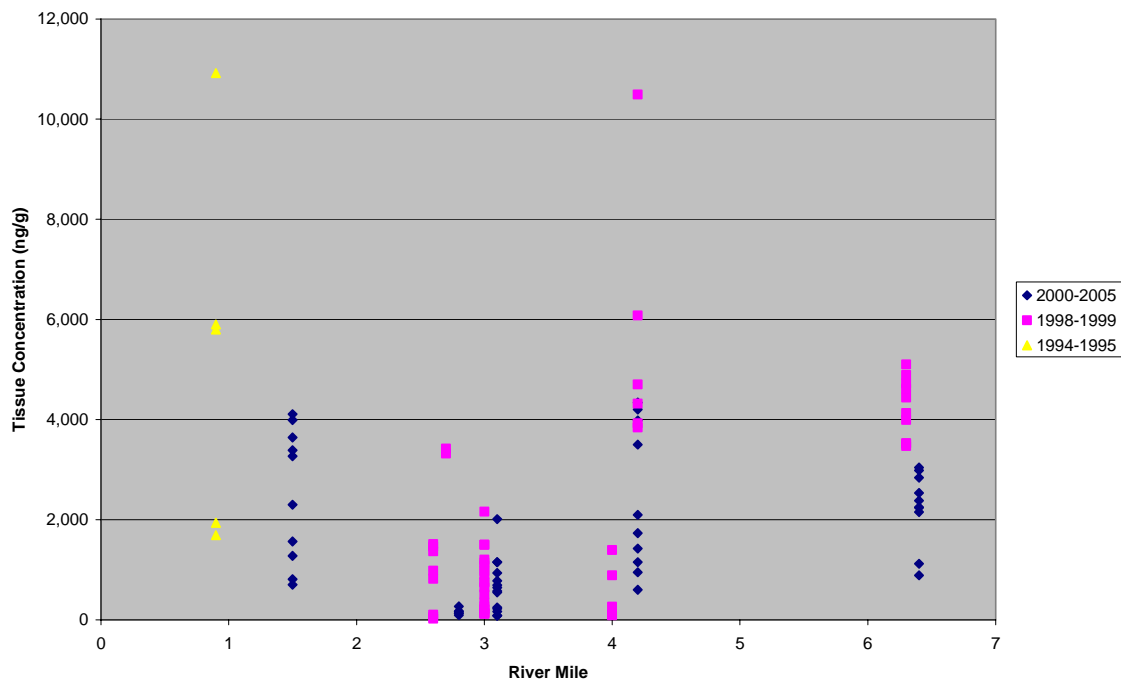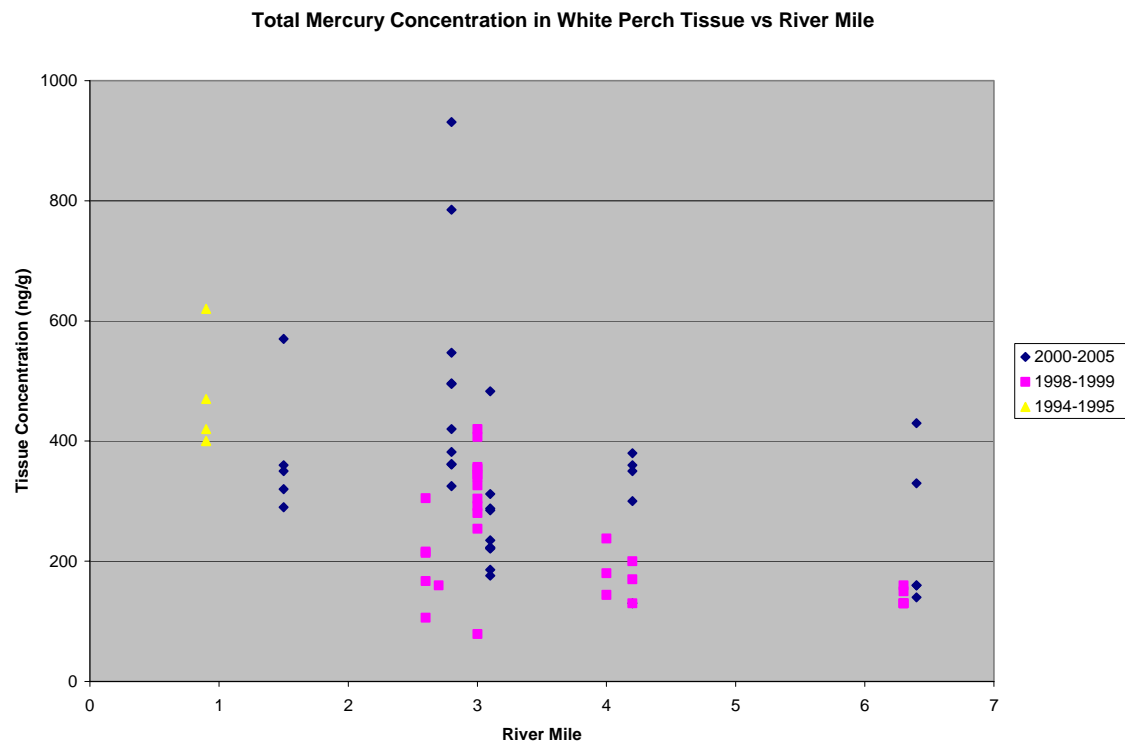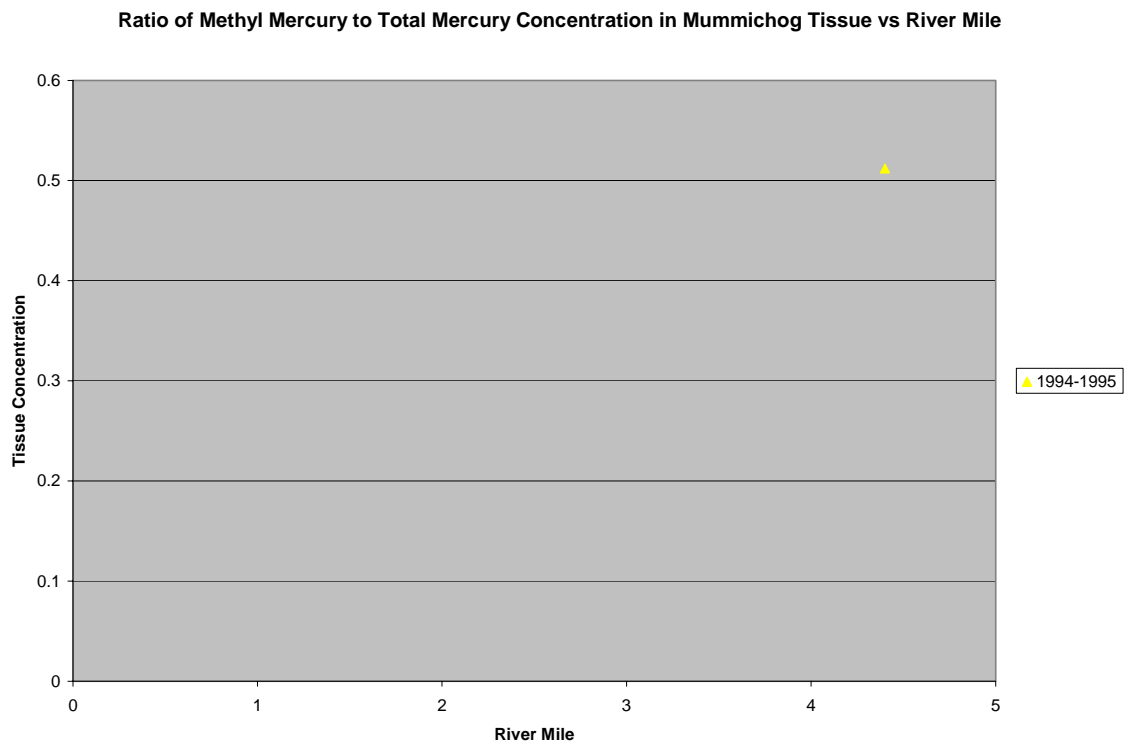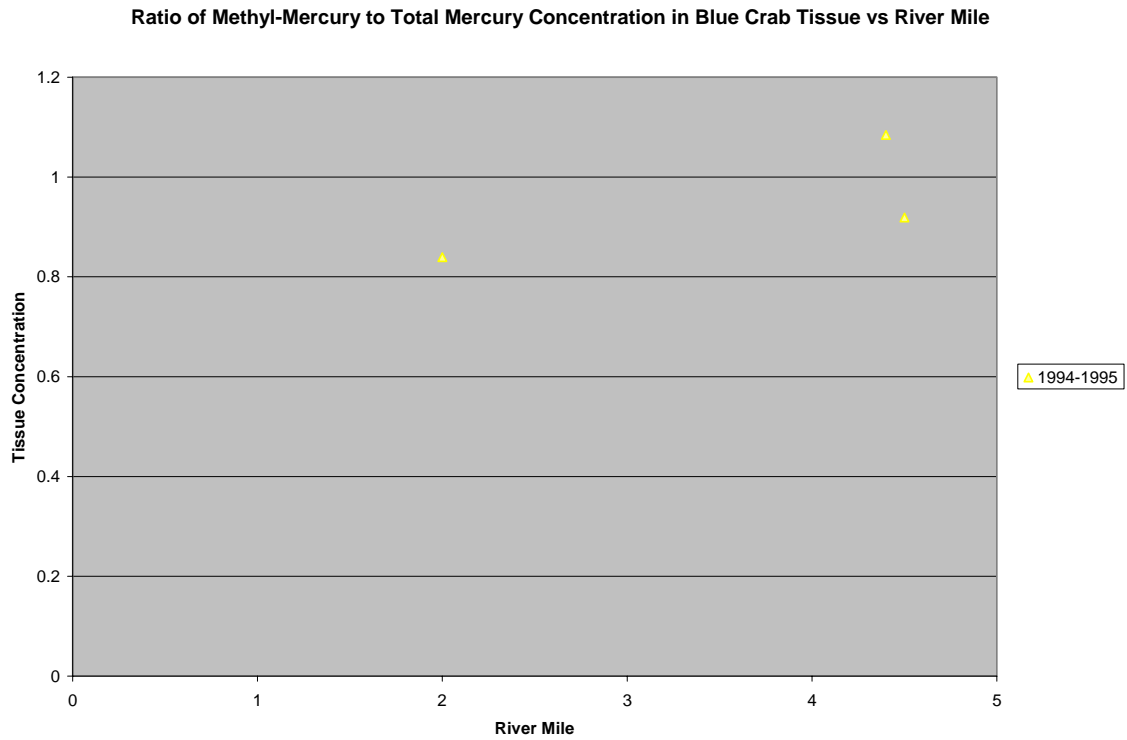
I.8 Total Lead

Total Lead Concentration in Blue Crab Tissue vs River Mile

Total Lead Concentration in Mummichog Tissue vs. River Mile
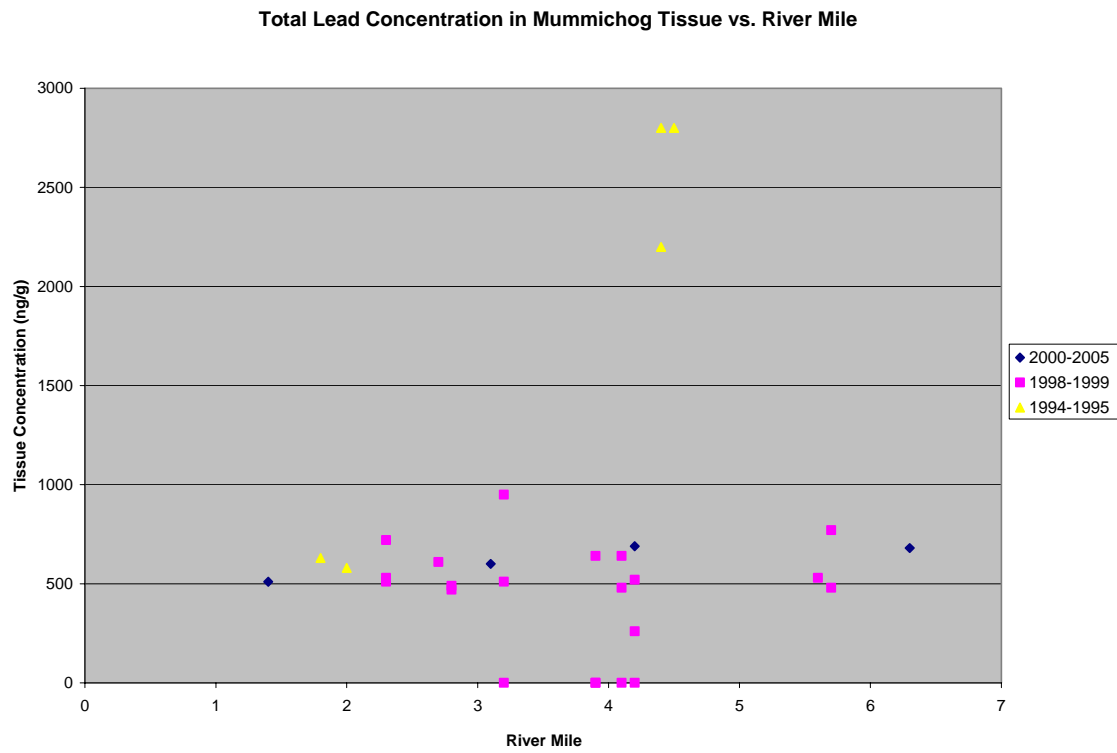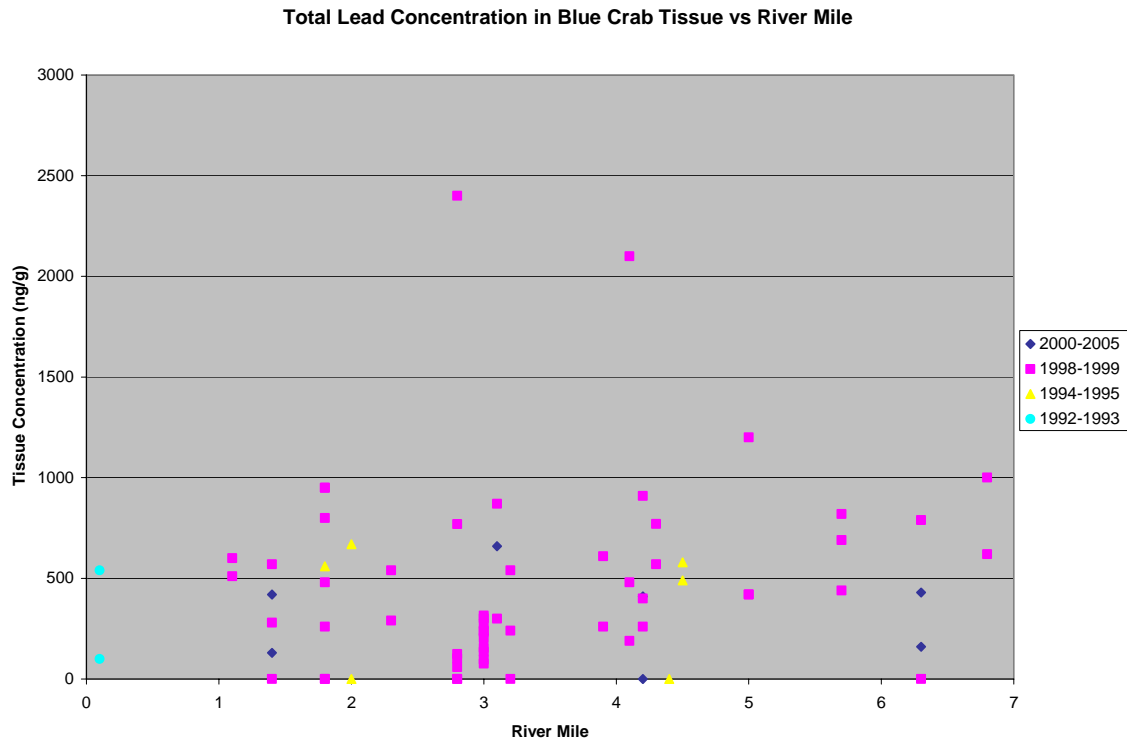
Total Lead Concentration in White Perch Tissue vs River Mile
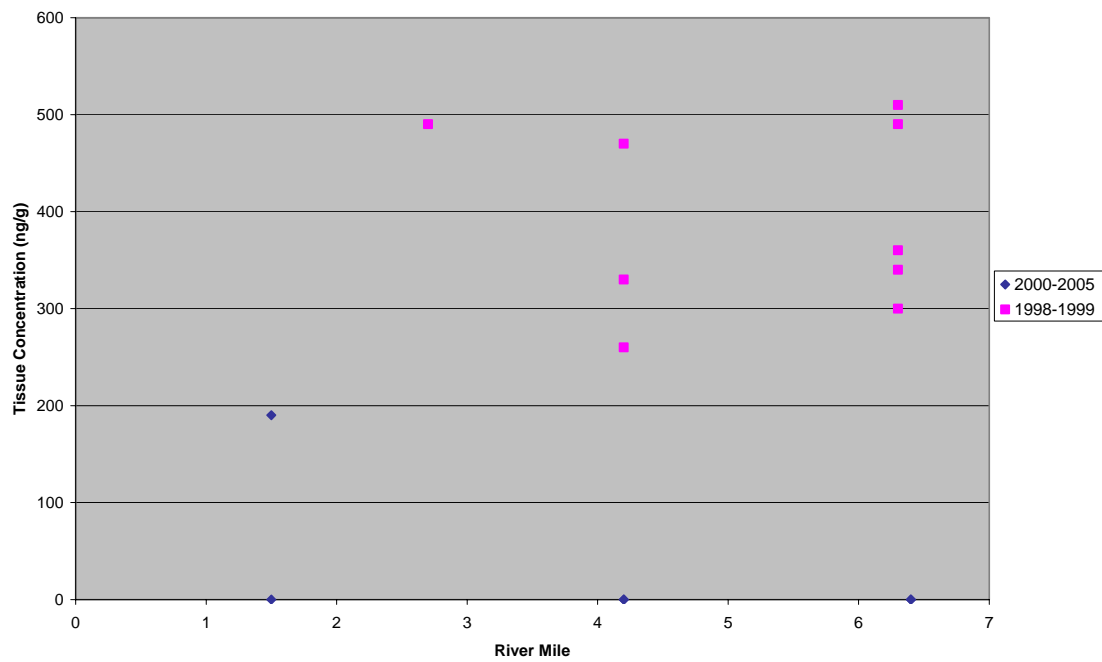
Deliverable II

II.1 Total DDT

Ratio of Total DDT Concentration in Blue Crab Tissue (lipid normalized) vs Concentration in Surficial Sediment (TOC normalized)
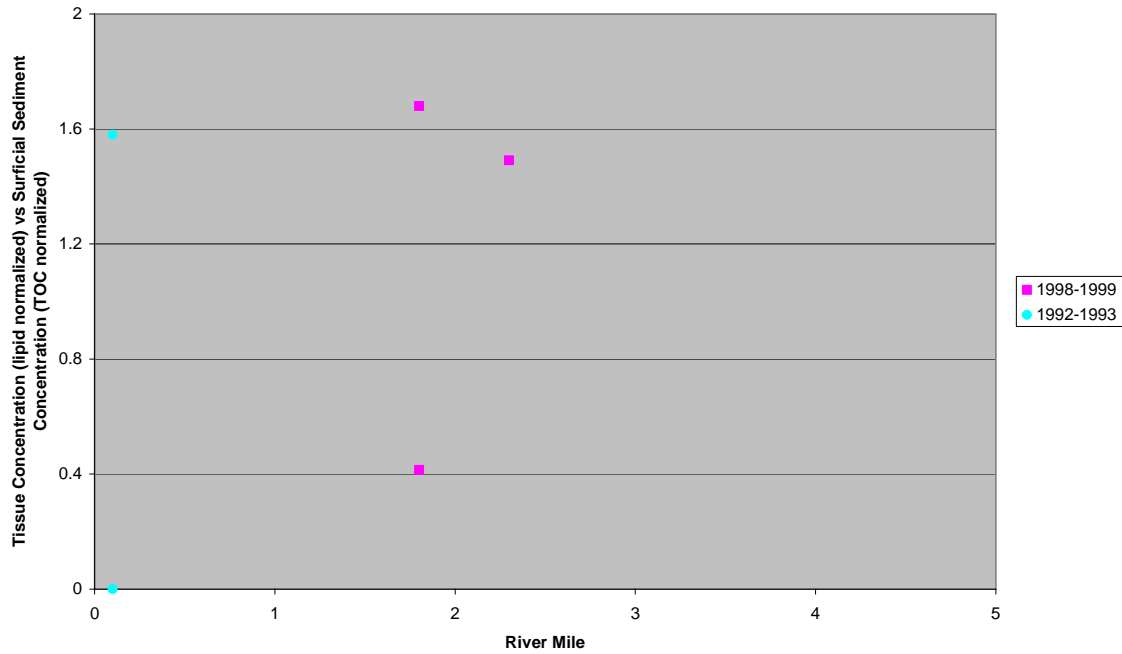
Ratio of Total DDT Concentration in Mummichog Tissue (lipid normalized) vs Concentration in Surfiical Sediment (TOC normalized) vs River Mile
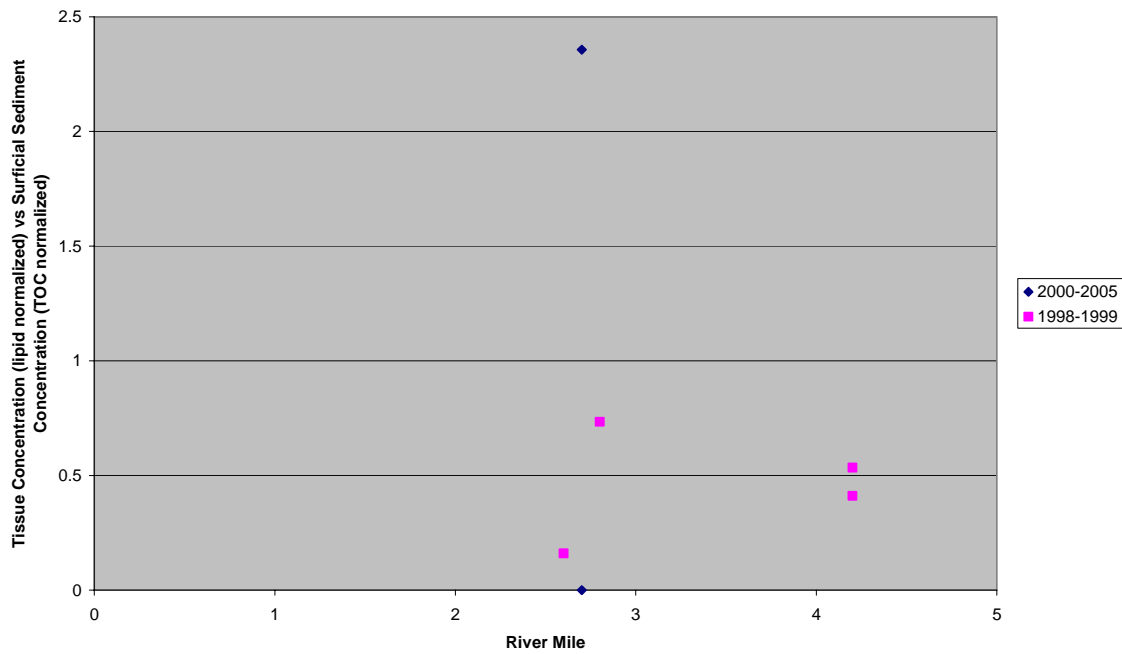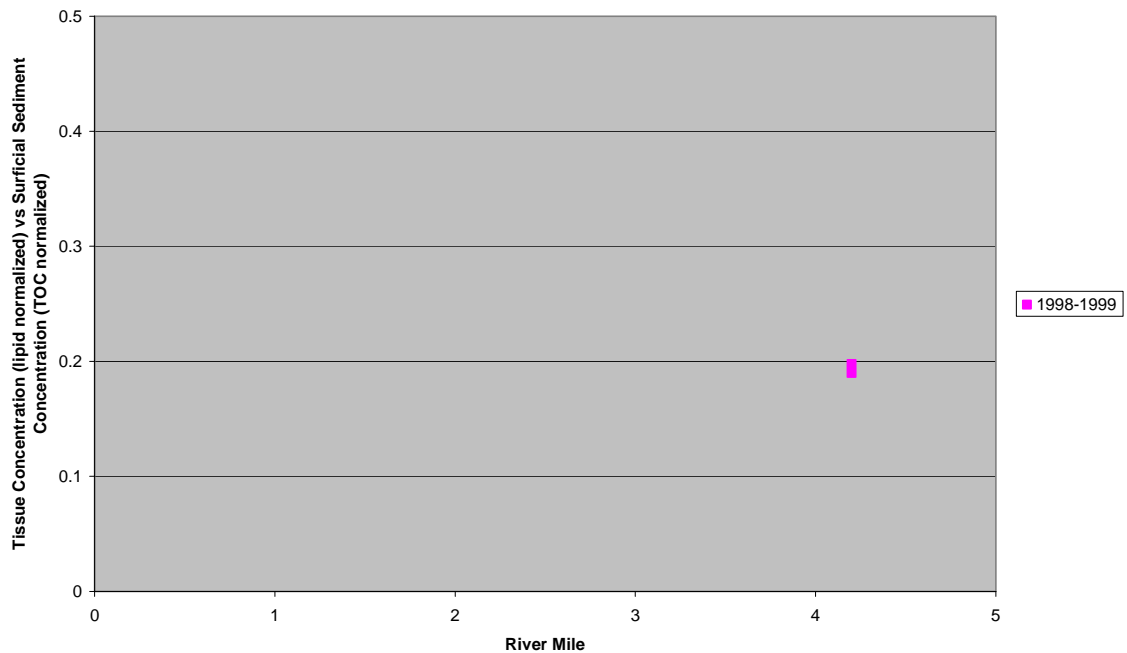
Ratio of Total DDT Concentration in White Perch Tissue (lipid normalized) vs Concentration in Surficial Sediment (TOC normalized) vs River Mile
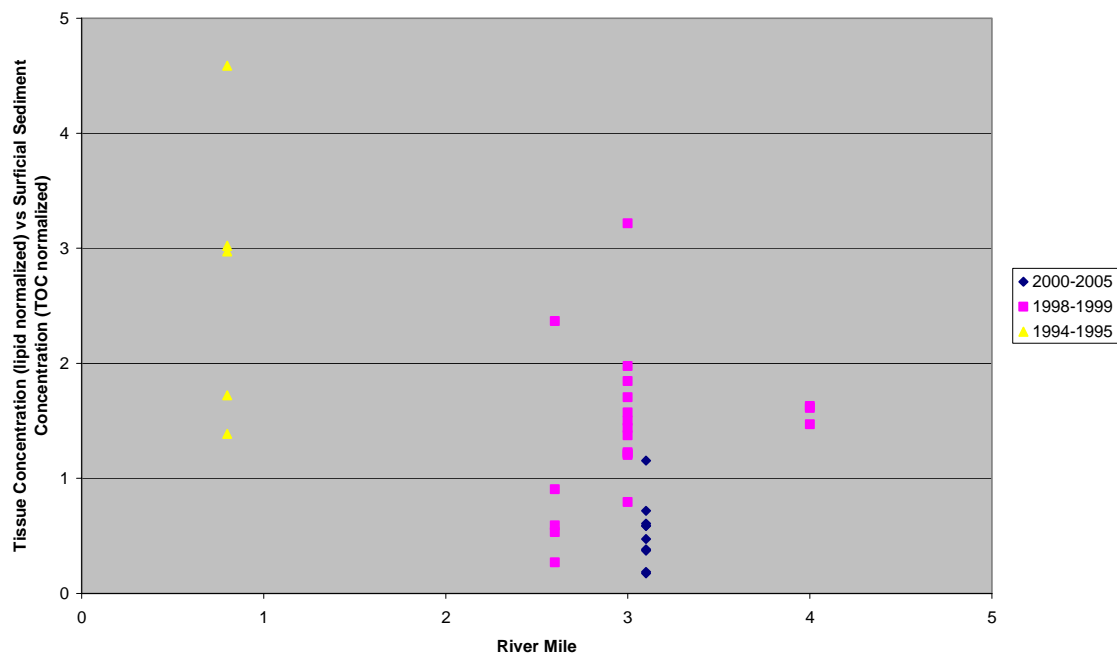
II.2 2,3,7,8-TCDD

Ratio of 2,3,7,8-TCDD Concentration in Blue Crab Tissue (lipid normalized) vs Concentraion in Surficial Sediment (TOC normalized) vs River Mile
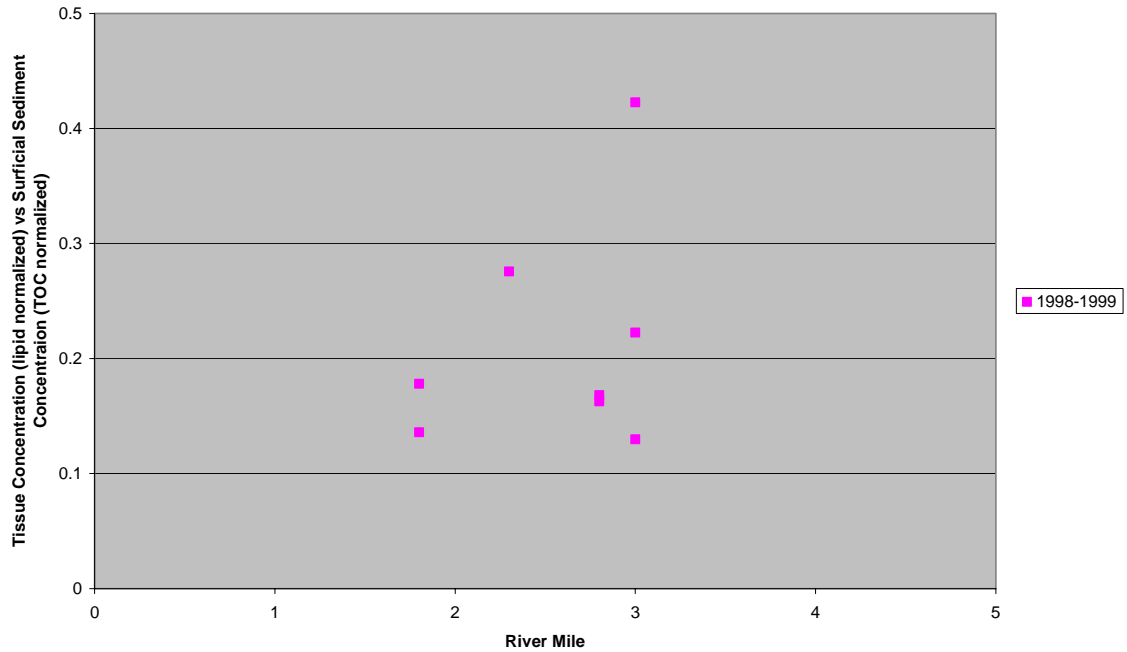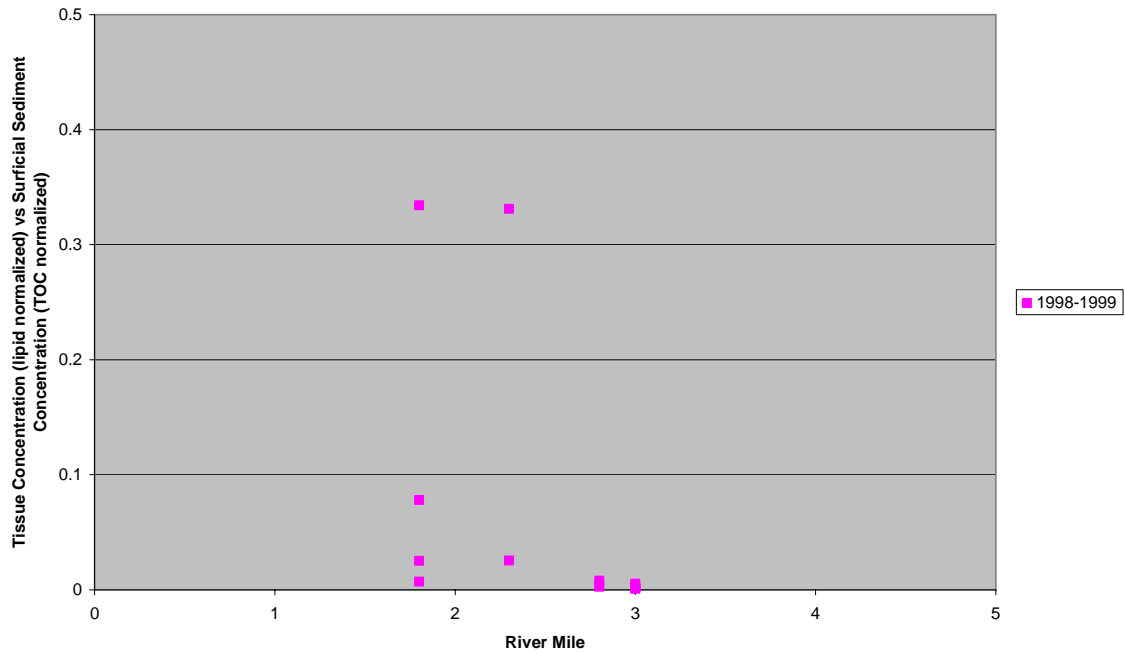

Ratio of 2,3,7,8-TCDD Concentration in Mummichog Tissue (lipid normalized) vs Concentration in Surficial Sediment (TOC normalized)
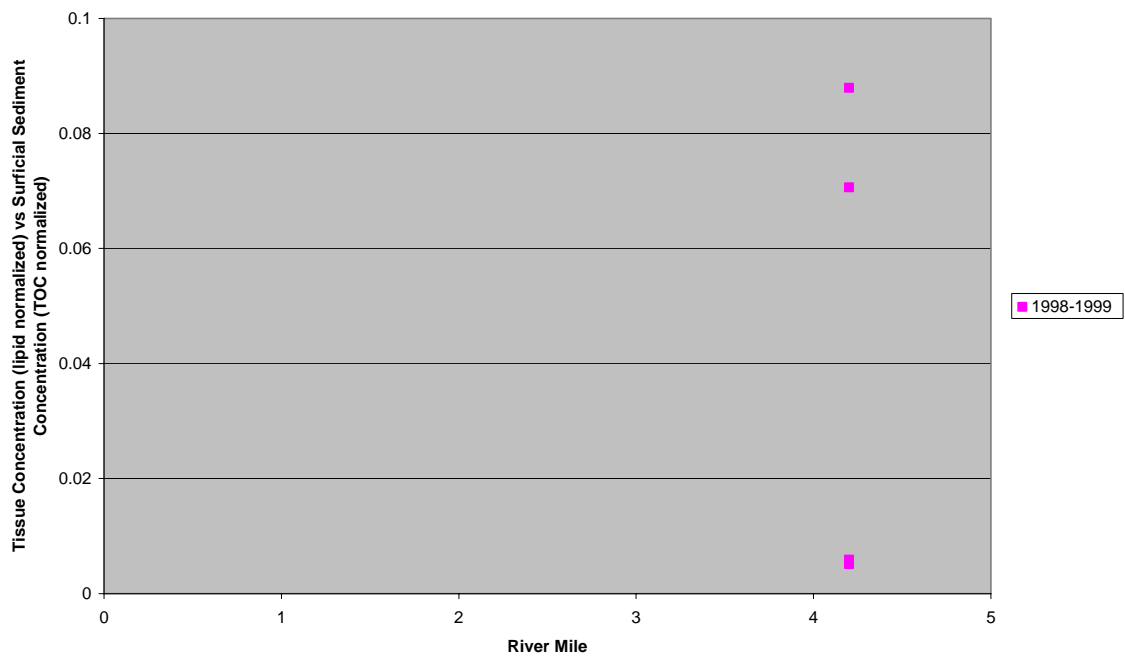
II.4 Total PAH

Ratio of Total PAH Concentration in Blue Crab Tissue (lipid normalized) vs Concentration in Surficial Sediment (TOC normalized) vs River Mile
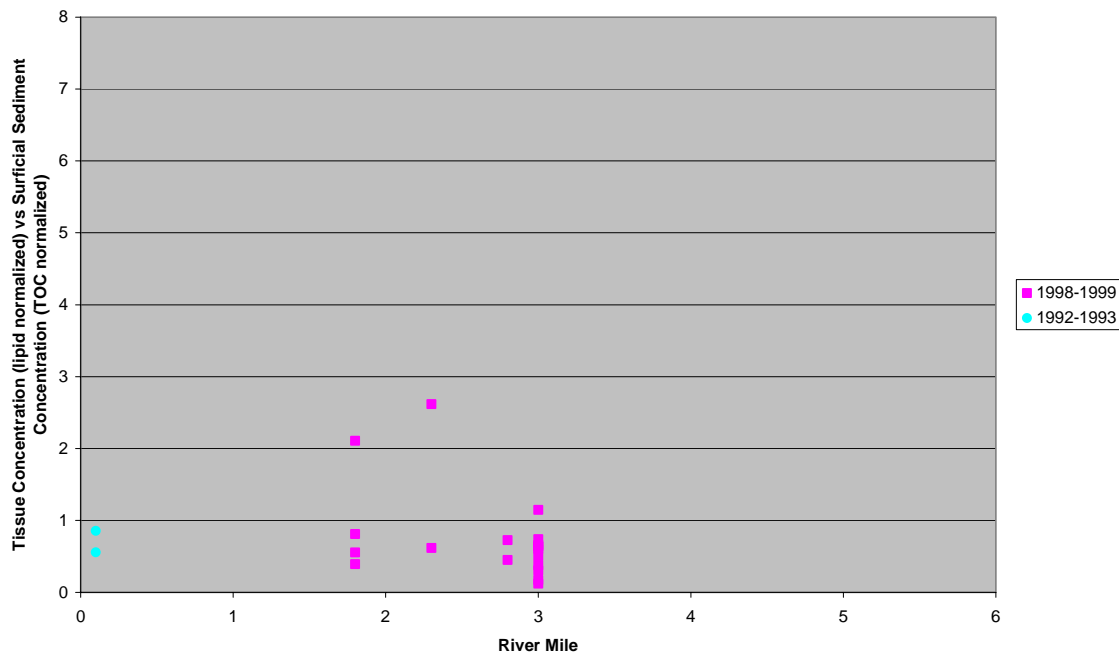

Ratio of Total PAH Concentration in Mummichog Tissue (lipid normalized) vs Concentration in Surficial Sediment (TOC normalized) vs River Mile
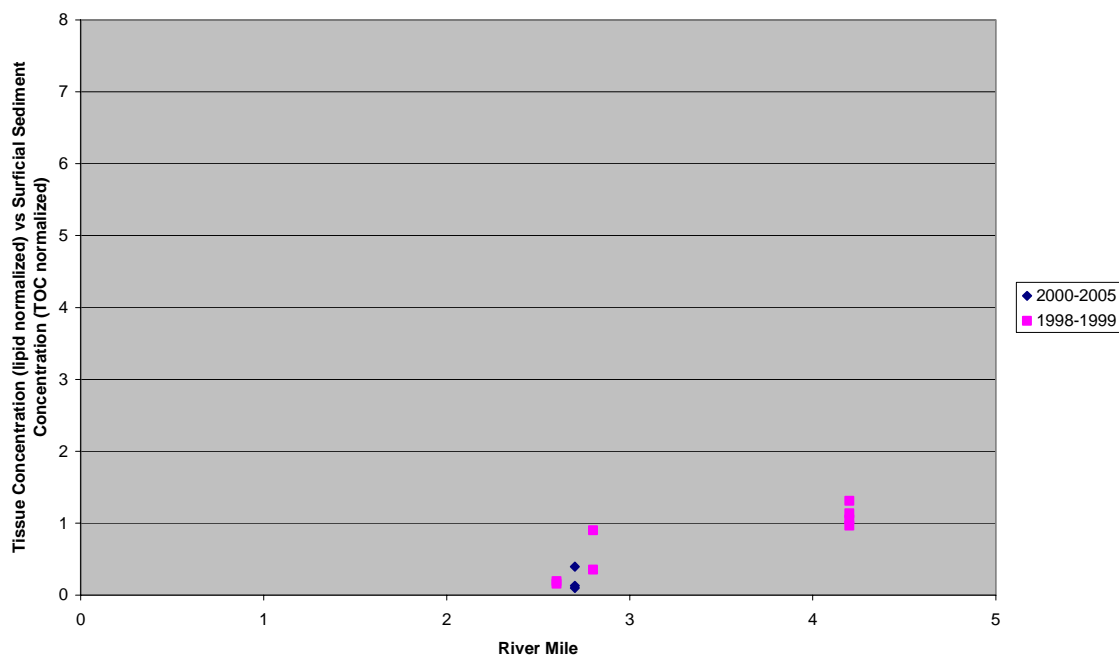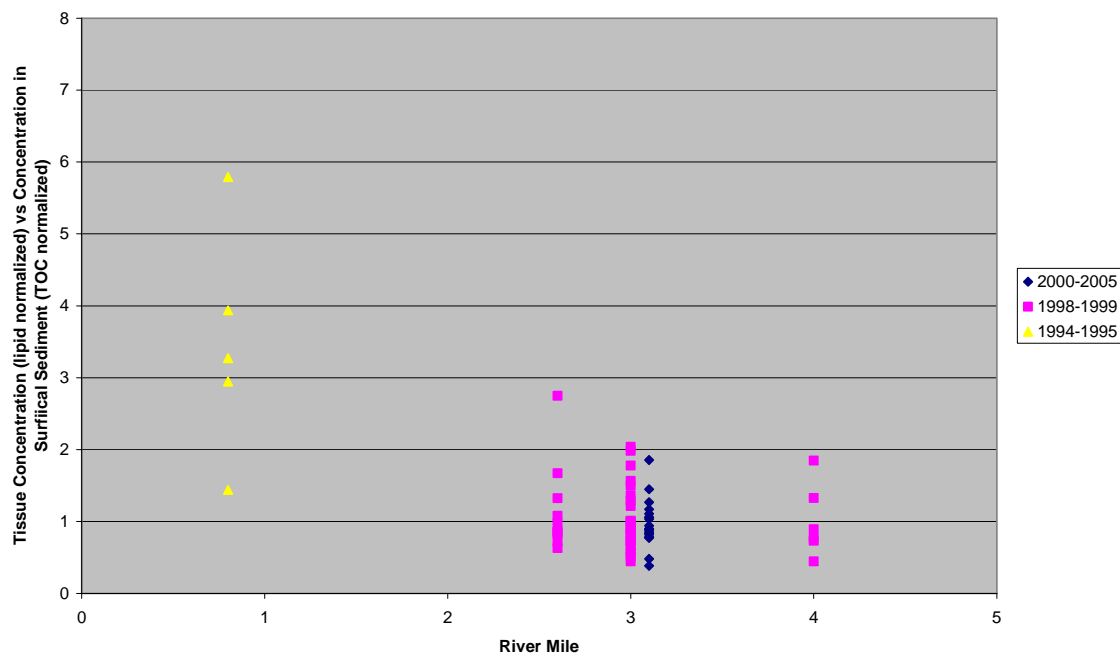
II.5 Total PCB

Ratio of Total PCB Concentration in Blue Crab Tissue (lipid normalized) vs Concentration in Surficial Sediment (TOC normalized) vs River Mile

Ratio of Total PCB Concentration in Mummichog Tissue (lipid normalized) vs Concentration in Surficial Sediment (TOC normalized) vs River Mile
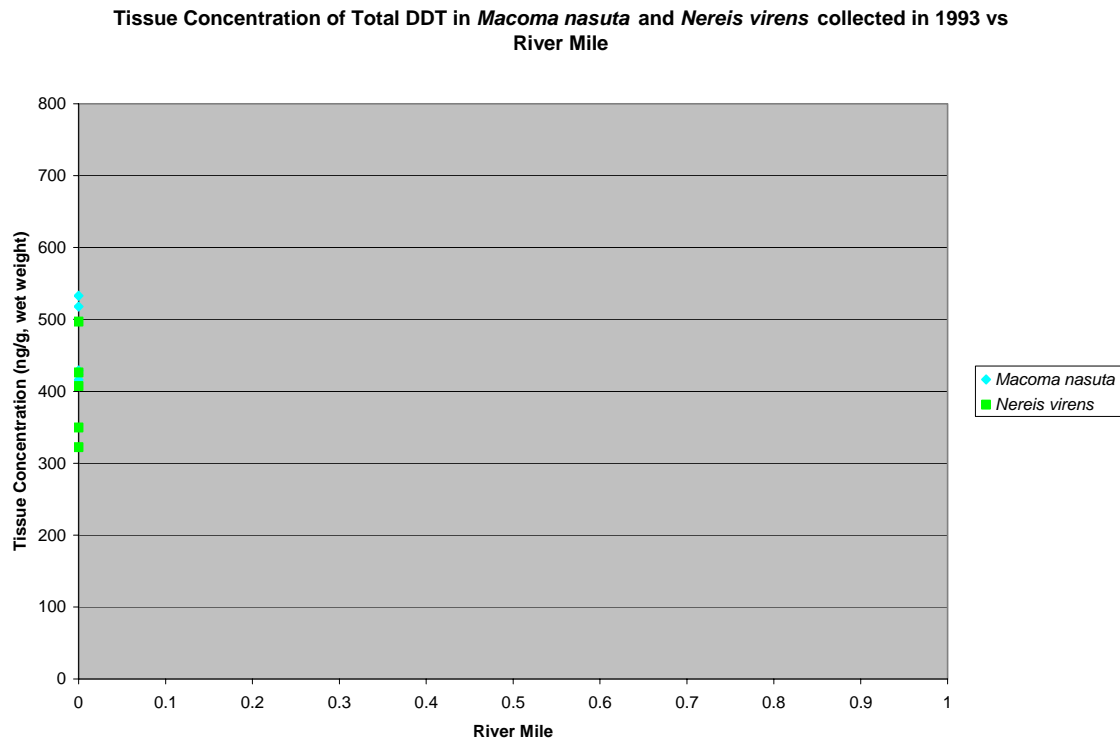

21

Ratio of Total PCB Concentration in White Perch Tissue (lipid normalized) vs Concentration in Surficial Sediment (TOC normalized) vs River Mile
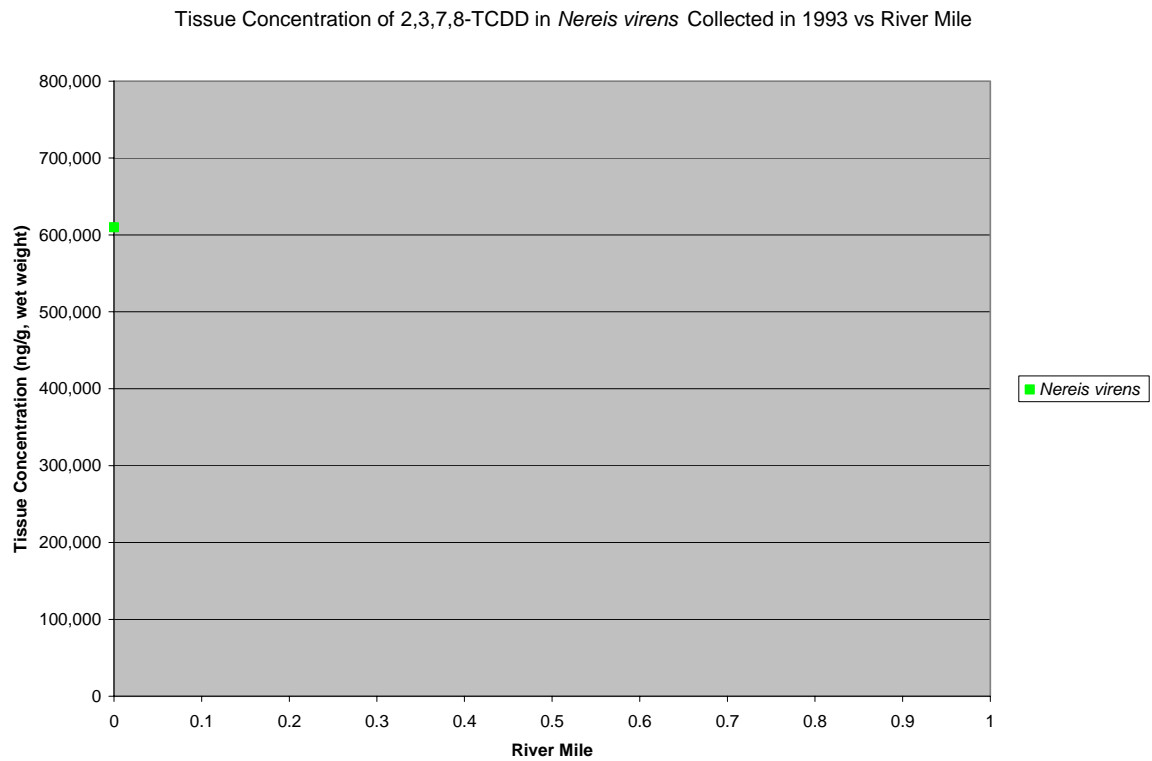
Deliverable III
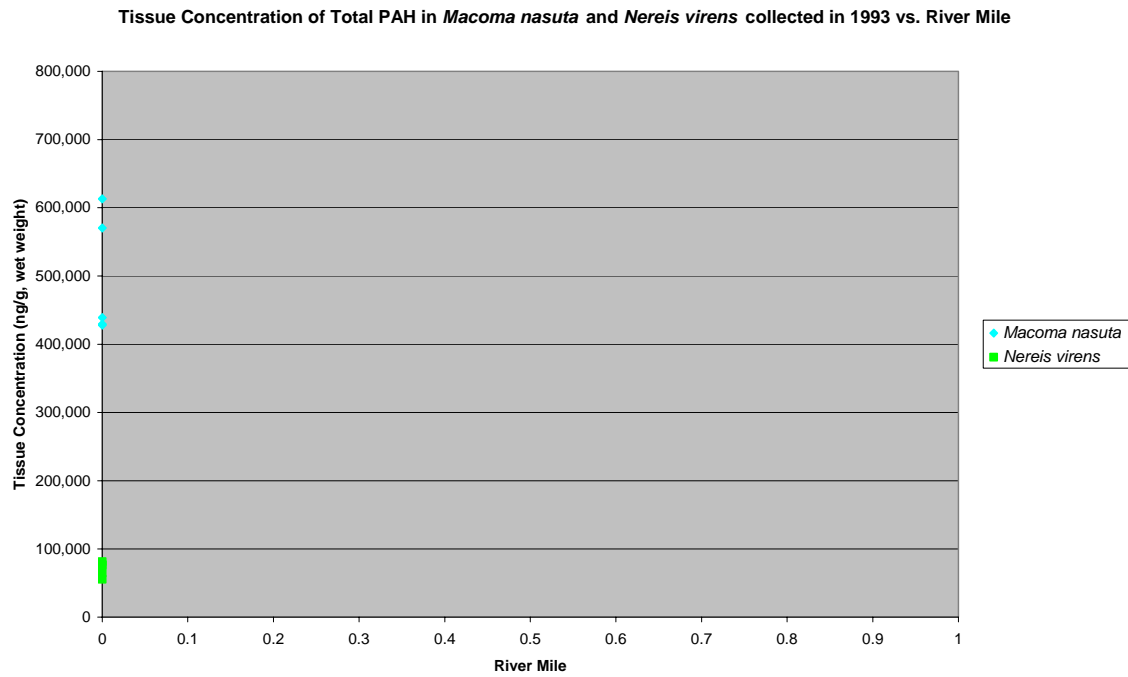
III.1 Total DDT

Tissue Concentration of Total DDT in *Macoma nasuta* and *Nereis virens* collected in 1993 vs River Mile

III.2 2,3,7,8-TCDD

Tissue Concentration of 2,3,7,8-TCDD in *Nereis virens* Collected in 1993 vs River Mile

III.3 Total PAH

Tissue Concentration of Total PAH in *Macoma nasuta* and *Nereis virens* collected in 1993 vs. River Mile

III.4 Total PCB

Tissue Concentraion of Total PCBs in Macoma nasuta and Nereis virens collected in 1993 vs
River Mile

III.5 Total Mercury

Tissue Concentration of Total Mercury in *Macoma nasuta* and *Nereis virens* collected in 1993 vs River Mile

III.6 Total Lead

Tissue Concentration of Total Lead in *Macoma nasuta* and *Nereis virens* collected in 1993 vs River Mile